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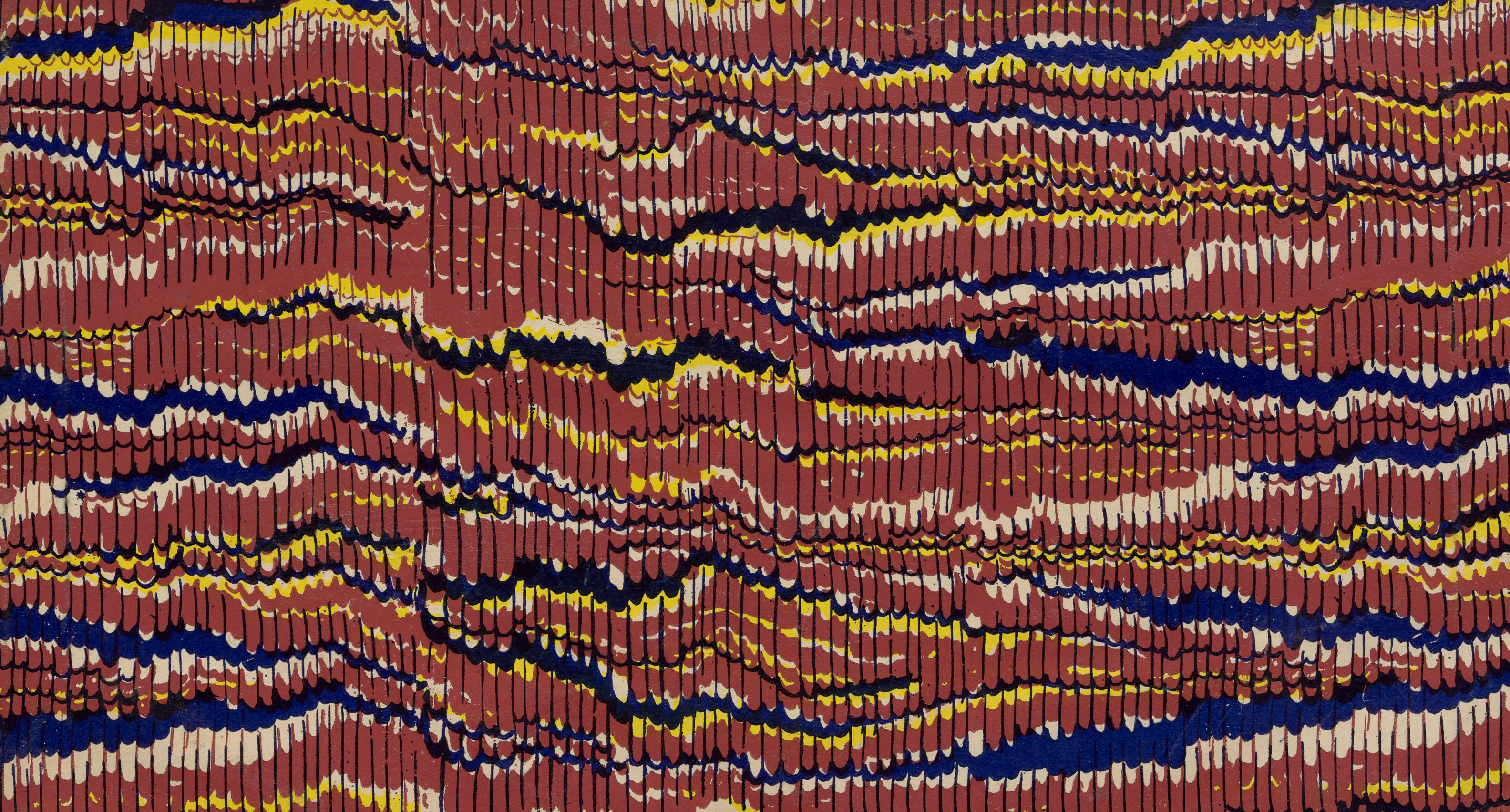

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THE ORDER HEMIPTERA IN NEW ZEALAND.

With Special Reference to its Biological and Economic Aspects.*

By J. G. MYERS, F.E.S., Biology Section, Department of Agriculture.

THE object of the present paper is briefly to indicate the state of our present knowledge—or, rather, lack of knowledge—of the Hemiptera of New Zealand; to point out its importance from the systematic, economic, and biological viewpoints; and to show how much must be done before the order is even approximately "worked out" to the same extent as, for example, the Lepidoptera. If this necessarily sketchy summary leads any one to collect or rear or study Hemiptera its purpose will have been amply fulfilled.

"There is probably no order of insects that is so directly connected with the welfare of the human race as the Hemiptera; indeed, if anything were to exterminate the enemies of Hemiptera we ourselves should probably be starved in the course of a few months." That is the statement of David Sharp, who, although a general authority on entomology, is nevertheless a coleopterist, and therefore not likely to assign undue importance to another order of insects.

The Hemiptera, or Rynchota, as a whole, including all those insects to which alone the English term "bug" is correctly applied, form the most isolated of the old Linnean orders. Even if we include the Anoplura, or lice, as extremely degenerate bugs specialized for a parasitic life, the homogeneity of the order is still remarkable; and this in spite of the fact that the Hemiptera include a vast number of diverse types which range over almost every station capable of sustaining insect-life, and even extend their habitat to positions in which they are the sole representatives of the tracheate Arthropoda. I refer particularly to the bugs of the heteropterous genus *Halobates* Esch., which live on the surface of the open ocean and apparently never voluntarily touch land.

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* A paper read at the New Zealand Institute Science Congress, Palmerston North. January, 1921.

An interesting study in convergent evolution is furnished by hemipterous insects, which, insinuating themselves into every available niche in the scheme of nature, have in many cases, by adaptation to similar conditions, achieved a truly surprising degree of superficial resemblance to the other arthropods with which they dwell. Thus New Zealand possesses bugs which present the external appearance of various beetles, Neuroptera, and even of Opiliones, or so-called "harvest-spiders."

Morphologically, the possession of suctorial mouth-parts, combined with a so-called incomplete metamorphosis, places the order in a unique position. With regard to the metamorphosis, which approaches the complete form in the cicadas and scale insects, so little work has been done in rearing these insects that our knowledge is fragmentary in the extreme. There appear to be five nymphal instars between the egg and the imago; but this varies not only with the species but in individuals of the same species. This ignorance of the preparatory stages prevails not only in New Zealand (where, outside the Coccidae, the life-history of only one Hemipteron has been even approximately sketched), but even in Europe and America, where the number of complete life-histories on record is paltry compared with that of many other orders of insects.

I do not propose here to enter into a discussion either of the classification or of the phylogeny of this fascinating order, but to proceed at once to specific examples, which I propose to treat family by family.

The number of Hemiptera described from New Zealand, exclusive of Psyllidae, Aleurodidae, and scale insects, is eighty-eight.* Kirkaldy in 1908 had "no hesitation in estimating at least 750 species of endemic Hemiptera for New Zealand," and he regarded this as "really much too little." However, notwithstanding the fact that little advance has been made in our knowledge of the order since then, appearances are rather against such a large estimate. Dr. E. Bergroth, the highest living authority on the Heteroptera, in a private letter, considers that, with regard to this suborder at least, Kirkaldy was greatly mistaken. Be that as it may, new forms are taken on almost every excursion, and vast numbers of new species certainly await description.

In connection with the metamorphosis it should be remembered that, as Kirkaldy puts it, the terms "larva" and "pupa" "have no place rightly in the horismology of the Homomorpha," all the instars from egg to imago being known as "nymphs."

FAMILY PENTATOMIDAE (CIMICIDAE KIRK.)—SHIELD-BUGS.

The Americans, acutely conscious of the flavour of fruit over which bugs of this family have been crawling, name them "stink-bugs." These insects certainly possess particularly well developed those glands which, opening one on each side of the thorax near the middle coxae, exude a volatile liquid with in some cases a pleasant, fruity odour, in others a characteristic and insufferable stench. It is usual to regard the possession of these odoriferous glands as extremely valuable in protecting the insects from the attack of birds; but the long-continued investigations of the United States Biological Survey into the relations between birds and insects have demonstrated that this theory does not always receive the support of facts, as the following quotation will show: "Among Hemiptera the Pentatomidae have a most nauseous smell and taste, as many discover when they accidently take them into the mouth with a berry; in fact,

* This does not include the Aphididae, which are all introduced.

they have received the vernacular name of 'stink-bugs.' It is evident, however, that birds do not find them nauseous or in any way disagreeable, for they eat them freely; in fact, few insects are found in the stomachs of so many species of birds and of so many individuals." (*Year-book, Department of Agriculture* (U.S.), 1908, p. 343.)

Other enemies are, however, apparently repelled, as the following quotation from those careful observers, the Peckhams, will show: [Referring to a large lycosid spider] "One day we gave her a large stink-bug, one of the Pentatomidae. She at once caught it, but when it sent off its terrible odour she dropped it and drew back in haste. The odour was so powerful that the spider fell over on to one side, throwing up all the legs on the side toward the bug, in the most comical fashion. We now feel quite confident that stink-bugs are protected from spiders." (*Instincts and Habits of the Solitary Wasps*, p. 161.)

This, which elsewhere is one of the largest families of the Heteroptera, is represented by nine species only in New Zealand. Of these, four are among our commonest bugs; while of the others, four are essentially Australian species, occurring only sparingly in this country.

The family is usually considered phytophagous; but at least two and probably more of our species are carnivorous.

Oechalia consocialis Boisd. is a brownish bug easily recognized among New Zealand species by the sharp spine on each side of the prothorax. Although of wide Australian distribution, it is apparently confined, in this country, to the Auckland District. A closely allied species of the genus performs good service in Hawaii against the sugar-cane leaf-hopper (*Perkinsiella saccharicida* Kirk.). According to Froggatt the species under discussion feeds in Australia on the larvae of *Phalaenides glycine*, the vine-moth, and of *Galerucella semipullata*, a destructive leaf-beetle.

Cermatulus nasalis Westw. is our largest common bug, and one which, on account of its carnivorous habits, is of great value to agriculture. On cultivated ground it may be found commonly attacking the larvae of the noctuid moths *Agrotis ypsilon*, *Cirphis unipuncta*, *Chloridea obsoleta*, and *Melanchra composita*, all of which, known as "cutworms" and "army-worms," inflict great damage on various crops. The pupae of these moths, when sufficiently exposed, are sucked dry with the same avidity as a plump caterpillar is reduced to an empty skin. *C. nasalis*, with its flattened, almost circular nymph of a shining black, marked with white and reddish, is found in a great variety of situations, and is by no means circumscribed in its diet. Larvae of any kind are probably acceptable; but what one would consider rather unlikely insects are attacked, and I have elsewhere recorded an instance in which a cicada much larger than the bug itself was the victim. The view that the actual sheath (labium) of the rostrum pierces the prey has been long since exploded. Only the setae enter the wound; but their strength must be tremendous, since they can suspend in mid-air a very much larger insect, which may be aided by the purchase furnished by ample wings.

Dictyotus caenosus Westw. is a species rather smaller than the preceding, of a more uniform brown colour, ornamented by a lateral chequering of the abdomen. It is fairly common among grass and low herbage, or crawling on paths. Practically nothing is known of its habits, at least as far as New Zealand records are concerned.

Rhopalimorpha obscura Dall. The process of sweeping in grass and low herbage almost anywhere in the open brings to light large numbers of this common and rather variable species. Both sexes may be easily

recognized by the pale, median dorsal stripe. In spite of its abundance, however, no bionomic notes have been recorded concerning this insect.*

Oncacontias vittatus Fabr., a very handsome species with which probably every one is familiar, is of a brilliant green colour marked with reddish and bearing a white spot on each corium. As its colour might indicate, it is more arboreal than any of the preceding species. It may be beaten from a great variety of plants, and is frequently brought under notice by a habit of crawling in the hot sunshine on roads and fences, where its bright colour renders it highly conspicuous.

Glaucias amyoti White is a typically Australian insect, and stands out as an evident exotic from any New Zealand collection in which it may find a place. In spite of its comparatively large size and brilliant coloration it is by no means conspicuous among leaves. In this country, however, it is by no means common in any locality. The extremely closely allied *Nezara viridula* Linn., which is practically cosmopolitan, has been recorded from the Dominion; but I have not met with it. In the United States it inflicts considerable damage on various fruit-trees, in some cases rendering large quantities of fruit unfit for use. At their present state of scarcity neither of these species requires much notice from an economic point of view. Both *Glaucias amyoti* and *Cermatulus nasalis* have been recorded as preying upon the pear "slug" (*Eriocampoides cerasi*). "The bugs may be seen on the underside of a leaf, and the 'leeches' on the upper; one of these bugs then thrusts its beak through the leaf and into the slug; both remain in position until the 'leech' is destroyed" (Broun).

FAMILY CYDNIDAE—BURROWER-BUGS.

The insects of this family present remarkable adaptations to a subterranean life. The front legs are flattened for the purpose of digging, and the whole form is squat, compact, and polished. Of the three New Zealand species, the shining black *Hahnia australis* Erichs., occasionally seen running over paths in the hot sunshine, is easily mistaken, at first sight, for a beetle such as *Adelium*, which favours similar situations, and progresses in the same hurried manner.

Chaerocydnus nigrosignatus F. B. White, with its mottled maroon and deep-brown coloration, burrows in the sand of the sea-beach, and bears a superficial resemblance to certain small lamellicorn beetles of similar habits.

FAMILY ARADIDAE—FLAT-BUGS.

This family is well represented in New Zealand by sombre-coloured, extremely flat-bodied bugs often found in large numbers under bark, and familiar to all who work in the bush. It is generally supposed that their food consists of fungous growths commonly found in the damp situations they frequent; but very little has been recorded on their habits.

One species, *Aradus australis* Erichs., a small sooty-black insect, occurs in a variety of situations and frequently appears in houses. The two other described species of the family, together with at least three others now awaiting description, are confined to the bush, where the nymphal stages of all of them and the whole life-cycle of most are passed in the typical habitat of the family.

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* Since writing the above I have found both imagines and nymphs of this species sucking the juices of cocksfoot (*Dactylis glomerata*) seeds and stems, particularly when the former are full grown but still at the milky stage.

All these insects are well supplied with the typical heteropterous scent-glands, opening as usual on the dorsa of certain abdominal segments of the nymph and on the thoracic pleura of the imago.

FAMILY BERYTIDAE.

I must pass over the single New Zealand example of this family without further remark than that it is brachypterous, as it is a rare insect, of the habits of which I know nothing. It may be beaten from masses of creeper in the forest clearings.

FAMILY LYGAEIDAE (= MYODOCHIDAE).

We now come to a family of flower-haunting and plant-eating bugs of which several species are common in gardens and cultivated areas generally. Among the injurious lygaeid bugs of other countries may be mentioned the notorious chinch-bug; but in this country none of the endemic species has yet been found harmful.*

Of the eleven described species, the beautiful dove-grey *Arocatus rusticus* Stål, found also in Australia, and distinguished by the red collar and abdomen, occurs commonly beneath bark, especially on white-pine logs, and also in thick masses of creeper, such as *Parsonsia* (*teste* T. Cockcroft). In these situations the whole life-history is spent.

The species of *Nysius*—small brown bugs which make speedy and objectionable use of their odoriferous glands on the slightest occasion—display a great predilection for the flowers of composites, whether they be marguerites and daisies in our gardens or celmisias in the alpine herb-fields and fell-fields. This applies especially to *N. clavicornis* Fabr. and to one or two at present undescribed species. *Nysius anceps* White is remarkable for its brachyptery. I think that if macropterous individuals do occur they must be extremely rare.

The shining dark-brown *Margareta dominica* White frequents the large clumps of species of *Gahnia*, from the seeds of which it is extremely difficult to distinguish it. The whole life-cycle is passed on this plant.

Several undescribed lygaeids occur commonly in leaf-mould.

FAMILY PYRRHOCORIDAE—RED-BUGS.

This family, important since it contains the cotton-stainer bugs and various species injurious to fruit, finds a place on the New Zealand list by virtue of a single recorded occurrence of the Australian *Dindymus versicolor* H.-S., a brilliant black-and-red insect probably introduced accidentally.

FAMILY TINGIDAE—LACE-BUGS.

Few insects can exceed the delicate beauty of these very attractive bugs. They are easily recognized by the broad leaf-like expansions of the prothorax and tegmina, the veins of the latter tremendously thickened and enclosing smooth, transparent areas presenting altogether an appearance which amply justifies the popular name of "lace-bugs." In keeping with their pleasing exterior the members of this family possess little of that evil smell which renders unpopular most of the other Heteroptera.

The Tingids are essentially phytophagous, some of them ranking, in other countries, among injurious forms; while one species was introduced

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* *Nysius huttoni* White, however, occurs in phenomenal numbers in fields of lucerne, where its attack must act as a continual drain on the crop.

from Mexico into the Hawaiian Islands to check the spread of the lantana weed (*Latana camara*), an operation in which it was successful to an encouraging degree.

Until very recently no Tingidae had been recorded from New Zealand; but now a typical and beautiful species has been discovered, together with its intermediate stages, at Ohakune by Mr. H. Hamilton, to whom I am indebted for the only specimens—one imago and a nymph at about the third stadium. Tingids are usually dwellers among foliage and on the under-surface of leaves; but this probably endemic species was discovered in leaf-mould which was being examined for Coleoptera. I have received much interesting hemipterous material obtained by Mr. Hamilton in this manner.*

FAMILY NABIDAE.

Speaking from an economic point of view, we have here a family which, owing to its almost wholly predaceous habits, does a little towards mitigating the severity with which we indict the Hemiptera as almost wholly injurious.

Of the two described endemic species, *Reduviolus saundersi* F. B. White is included also among the Hemiptera collected by the Oliver Expedition to the Kermadecs in 1908. In addition there occur at least three other species, some or all of which are probably introduced. One delicate pale-green species has been found recently preying on the very common introduced Capsid (*Oncognathus binotatus* Fabr.) which is injurious to rye-grass, cocksfoot, and other grasses. Others devour lepidopterous larvae.

All the New Zealand Nabidae so far collected frequent ground herbage—scrub and grasses.

FAMILY GERRIDAE—POND-SKATERS.

While the economic importance of this family is practically negligible except in so far as its members supply food for fish, its biological interest is very great, since it is here we place *Halobates* Esch., a well-known genus of oceanic bugs which is lately recorded for the first time from the New Zealand subregion.† These rather insignificant-looking small grey bugs deposit their eggs on pelagic flotsam, and subsist by sucking the juices of floating animal matter such as dead jelly-fish, thus passing through the whole life-cycle at a distance from land.

Of the numerous and familiar fresh-water species of the family we have in New Zealand only one representative, *Microvelia macgregori* Kirk., a minute velvety-brown grey-banded pond-skater which may be seen running swiftly over the surface of the water in the quiet reaches of bush creeks. On the slightest alarm it is interesting to watch with what precision every insect rushes immediately to the shelter of the vegetation on the nearest bank, to venture forth again only when several minutes have elapsed and all is calm.

Up to the present only the apterous form has been described (Kirkaldy, 1908, 109). The alate form must occur extremely rarely in the lowlands, as I have taken only one specimen during a long period of collecting over several lowland localities in which the apterous form is very abundant. On the alpine tarns of Mount Hector, Tararua Range, at an elevation of

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* Since writing the above I have discovered a second species of Tingid frequenting swamp vegetation in the Wellington District. Specimens are in the hands of Dr. E. Bergroth for determination.

† *Trans. N.Z. Inst.*, vol. 53, p. 257, 1921.

4,500 ft., however, I took, in February, only the winged form, and that in considerable numbers. So far as I am aware, this is the first record of a change so great in the relative proportion of apterous and alate individuals with a change of elevation. In about nine lowland stations with otherwise varying conditions, from brackish water to artificial ponds, we have the alate form practically absent, while forty miles or so away, at an altitude of 4,500 ft., it is the only representative of the species.

The alate form is characterized in the following way: Very prominent lateral angles to thorax and hypertrophy of the thorax generally. The visible portion of the thoracic nota is strongly hexagonal. The disc of the nota, posterior to the yellowish border of the pronotum, is immaculate, sparingly punctate, practically black, with numerous short, golden hairs. The tegmina stretch just beyond tip of abdomen, and are a dull, smoky blackish-brown with a pale-whitish stone-coloured spot near the base and a large elliptical spot of similar colour near the apex. As the tegmina are folded so that the greater portion of the one completely covers the greater portion of the other, the distal white spot occupies a median position at the apex of the body. In many specimens the two pale spots on each tegmen are almost obsolescent. The line of snow-white hairs along the dorsal margin of the eye is very conspicuous.

FAMILY REDUVIIDAE—ASSASSIN-BUGS.

In this we have another beneficial family of predatory insects.

Peirates ephippiger A. White is a large Australian species, very rare except in the north of this Island. I have been unable to study the habits of this insect. It is wholly predaceous.

Of the long-legged insects of the genus *Ploiaria*, bearing a superficial resemblance to Opiliones, and found in the same situations crawling over moss-covered trunks in the bush, we have at least two species. In both, the manner in which the fore coxae are greatly elongated, and the tibiae applied to the spiny femora to form a vice exactly as in the praying mantis, is worthy of remark.

FAMILY HENICOCEPHALIDAE.

This exceedingly aberrant and widespread family is here represented by a typical species, *Henicocephalus maclachlani* Kirk., which occurs in the evening, dancing in swarms in the air, in a most gnat-like fashion, and during the day has been found, together with its nymph, by Mr. Hamilton, in the leaf-mould before mentioned. The peculiar swollen head, together with the almost clear and homogeneous tegmina, give this insect an appearance like that of no other Heteropteron.

FAMILY ANTHOCORIDAE—FLOWER-BUGS.

These may be dismissed with the remark that, as the insects are very small and liable to be overlooked, it is very probable that many more than the three species at present described will eventually be brought to light. One of our species of the genus *Cardiastethus* occurs among decaying Agarics and other fungi, where its nymph is also found.

FAMILY CLINOCORIDAE.

New Zealand is by no means free from the cosmopolitan representative of this family—namely, the bed-bug, *Clinocoris lectularius* Linn.; nor is it confined to the larger centres of population. Mr. Elsdon Best assures me,

however, that it was almost certainly unknown to the Maoris before the advent of the white man. There is no record of any such insect in the comprehensive traditions of the race.

FAMILY MIRIDAE—PLANT-BUGS.

Of the vast number of these fragile insects which come under the notice of every collector, only eight species have up to the present been described. The task of working out these bugs is rendered very hard by the difficulty of distinguishing between the endemic species and the probably large number of introduced forms.

Romna scotti F. B. White is a large, showy species frequenting flowering manuka (*Leptospermum scoparium*); while *R. capsoides* White is even larger and more striking.

Of the introduced forms the most common and injurious at the present time is the handsome green and blackish *Oncognathus binotatus* Fabr., which is now (January) in almost incredible numbers on perennial rye-grass, cocksfoot, and other grasses; so that the insects might be taken from the sweep-net almost by the handful—all stages, nymphs and imagines, being present. The insects may be seen inserting their beaks into the heads of the grasses, and moving quietly round to the opposite side when approached too closely. The imagines take wing very readily.

FAMILY ACANTHIIDAE (= SALDIDAE)—SHORE-BUGS.

Few of the families of Heteroptera are so distinct and homogeneous, both morphologically and biologically, as this. The insects are generally dark-coloured, soft-bodied bugs, the most prominent feature of which is the large eyes, the great efficiency of which will be vouched for by any collector who has attempted the capture of these exceedingly active insects. At a favourable season members of the typical genus *Acanthia* (= *Salda*) may be found running over the stones at the edge of the water on lake-shores and creek-beds. In cases where a stream is flowing into the sea the shore-bugs are common right to its mouth; but I have never found them more than a few yards from the fresh water. The nymphs, in many cases of a shining jet-black colour, frequent the same localities and display the same agility. Both nymphs and imagines run on the surface of the water with the same readiness as on the rocks; and the imagines use their wings on the slightest provocation. These bugs are said to feed on the juices of drowned flies and other flotsam; but it is evident that they find food also among the stones which they explore so assiduously.

FAMILY CORIXIDAE.

With regard to the economic status of this and the following family, their importance as a means of checking mosquitoes far outweighs their value as human food, in the often-quoted case of *Arctocorisa mercenaria*, the eggs of which form an article of diet in Mexico.

The common New Zealand corixa, *Arctocorisa arguta* F. B. White, occurs throughout the country wherever there is fresh water under the circumstances necessary for its environment.

Diaprepocoris barycephala Kirk. is an Australian form distinguished by its much shorter and stouter appearance, and concerning the occurrence of which in New Zealand there has been some question. There are, however, indubitable specimens, labelled "Auckland," in the Canterbury Museum.

FAMILY NOTONECTIDAE—WATER-BOATMEN.

There is probably no other family of insects so eminently and completely adapted to an aquatic life as the Notonectidae. The habit of living and swimming for ever on their backs would, in the absence of any other peculiarity, suffice to render these insects unique.

Two species, of the genus *Anisops*, occur fairly widely in this country. In both these the scheme of coloration is that adopted by many aquatic animals—namely, a shining white in this case on the dorsal surface, since this is always the under-surface, and a sombre tint on the ventral, which is uppermost. The water-boatman is thus more or less invisible when seen from below, with its white dorsum viewed against a light-coloured sky, while from above, every collector knows how difficult it is to distinguish the insects against the dingy background of the depths. The fact that, in the water-boatman, which swims in an inverted position, the lights and shades of the coloration are reversed supplies a proof, if such were needed, of the utility of the usual distribution of light and dark tints in many aquatic animals. Mr. Hudson has taken these insects in brackish rock-pools in company with larvae of the shore-mosquito (*Opifex fuscus*).

Leaving now the Heteroptera, we are next occupied with the Homoptera, an important suborder the members of which are almost exclusively phytophagous.

FAMILY CICADIDAE.

In the Cicadidae we have some of the most familiar insects in New Zealand. Their song seems a necessary concomitant of a hot summer's day. There are thirteen described species, all of which belong to the genus *Melampsalta* Amyot. There remain at least two more undescribed species,* and it seems probable that this by no means exhausts the list. There are records of an Australian member of the genus causing considerable damage to peach-trees, not only by ovipositing in the branches, but by the multitude of punctures made while actually feeding. No very serious complaints have yet been laid against the endemic cicadas; but the large *M. cingulata* Fabr. attacks a variety of native and cultivated trees, while the common *M. cruentata* punctures the stems of various herbaceous plants, including grasses. Observations are needed on the duration of the subterranean nymphal period.

FAMILY CERCOPIDAE—FROG-HOPPERS.

This very attractive family is represented by four species only, belonging to two typical and widespread genera, of which *Philaenus* contains the common three-spotted, green and reddish frog-hopper, and two rather scarcer pale-green ones, all of which frequent low herbage; while the other genus, *Cercopis* (= *Aphrophora*), has a single tree-haunting species practically confined to the bush. All the three spend the nymphal stages in those masses of froth known in England as "cuckoo-spit" and in France as "frog's saliva." No fewer than seven theories have at various times endeavoured to account for this frothy secretion, and even when the notion that the plant produced it and "generated" its insect inhabitant was given up it was still a subject for debate as to how the material was secreted. It is now well ascertained that the bulk of the liquid is emitted from the anus. Lateral abdominal glands at the same time secrete a mucilaginous substance which renders the clear anal fluid sufficiently viscous to retain

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* The two belong to the genus *Pauropsalta* God. & Frogg.

for an indefinite period the air-bubbles which are introduced into it from the stigmata.

FAMILY CICADELLIDAE—LEAF-HOPPERS.

For the purpose of the present paper I am treating as mere families both this superfamily and the succeeding one. The members of this family are popularly and quite appropriately known as "leaf-hoppers." With regard to their economic importance we may quote Professor Osborn: "In some estimates based on the abundance of insects actually collected in given areas I have claimed that from 25 to 50 per cent. of the growth of grass may go to feed these leaf-hoppers, and still all this loss may occur without meadow or pasture actually showing by wilted or withered plants that such a drain was occurring." Moreover, the actual damage consists not only in actual consumption of pasturage, but in the prevention of pollination and seed-production owing to the untimely extraction of sap from the immature floral organs.

At least one species of graminivorous leaf-hopper, probably introduced, occurs commonly in this country.

Only two endemic Cicadellids have yet been described. Of these, *Paradorydium westwoodi* White is remarkable for the amazing prolongation of the head, while *Athysanus negatus* White (?), presenting a more normal appearance, occurs in surprising numbers on a variety of scrubby bushes, notably *Cassinia leptophylla* (tauhinu), where its nymphs may be found even throughout the winter. These nymphs, by the way, are parasitized by a species of *Stylops*, which I have not yet succeeded in rearing to maturity.

Another *Paradorydium*, of an apparently undescribed species, frequents a rush-like plant, *Leptocarpus simplex*, on the stems of which it is almost impossible to distinguish the insect, with its produced head and long, bract-like tegmina. In striking correspondence with this excellent protective concealment, the insect has lost its wings, and in addition displays the greatest reluctance to move, thus contrasting strongly with the agile leaf-hoppers of other genera.

Of the introduced leaf-hoppers the most noteworthy is that which frequently causes considerable "scorching" of apple-leaves. This is a brilliant yellowish species identical with *Typhlocyba* (*Empoa*) *australis* Froggatt. It has evidently been introduced from Australia.

FAMILY FULGORIDAE.—PLANT-HOPPERS.

In this, the most highly evolved family of the Homoptera, we possess fourteen described species, of which the endemic forms are familiar as small, very active insects which hop off the collector's beating-sheet almost as soon as they reach it. The adults of *Oliarus* in particular, and to a greater extent the nymphs, are provided with a conspicuous white tuft of waxy, fibrous, flocculent material at the end of the abdomen. Both the purpose and the composition of this secretion are at present rather enigmatical.

Scolypopa australis Walk., a large and conspicuous species, with large transparent wings and tegmina banded with darker, an insect occasionally injurious to vines, especially in the north, has probably been introduced from Australia. After the *Cicadidae*, our most conspicuous and beautiful Homopteron is the vivid-green *Siphanta acuta*, particularly abundant in the Nelson District, where, together with its pale-green nymph, it feeds on ornamental shrubs, with which it is considered to have been accidentally introduced from Australia.

Sephena cinerea Kirk. is an introduced Australian species which carries "fireblight."

FAMILY PSYLLIDAE.—JUMPING PLANT-LICE.

Probably few families of New Zealand insects have received so little attention as the Psyllids. Of the five species at present recognized, the most noteworthy is *Rhinocola eucalypti* Mask., which occurs sometimes in large numbers on the young leaves and shoots of *Eucalyptus globulus*. Both nymphs and adults are covered with a white powdery material resembling the bloom-like efflorescence of the young gum-leaves themselves. In some Australian species this secretion is plentiful enough to form an item in the aboriginal menu ("lerp").

FAMILY APHIDIDAE.

No endemic aphids have yet been described from New Zealand; but a number of introduced forms are of considerable importance. I have been able to gather records of the occurrence of fifteen species in New Zealand, and as such a list has not been published since *Index Faunae*, 1904, it may be useful as a basis for future work: *Myzus cerasi* Fabr.; *M. persicae* Sulzer; *Aphis brassicae* Linn.; *Chermes strobi* Hartig (= *C. corticalis* Kalt.); *C. pini* Koch; *Schizoneura lanigera* Haus.; *Schizoneura ulmi* Linn.; *Phylloxera vastatrix* Planchon; *Neorhizobius graminis* Thompson; *Macrosiphum rosae* Reaum.; *M. granarium* Kirby; *Pemphigus populitransversus* Riley; *Aphis abietina* Walk.; *A. nerii* Fonsc.; *A. bakeri* Cowen.

In February last I took specimens of a green aphis among mixed alpine herbage at an elevation of 4,500 ft. on Mount Alpha, Tararua Range. If ever there were a locality for a native aphis it is here; but the specimens have been determined as *Macrosiphum granarium* Kirby, a widespread European species feeding on a variety of grasses.

It is not necessary here to detail the injuries inflicted on various crops by these insects. *Myzus cerasi*, *M. persicae*, *Schizoneura lanigera* (woolly aphis), and *Phylloxera vastatrix* may be mentioned in connection with the orchard and vineyard industry; *Aphis brassicae* and *Macrosiphum granarium* attack cruciferous and gramineous forage crops respectively, while *Schizoneura ulmi* crumples the leaves of introduced elms into huge pseudo-galls. True galls are formed on the petioles of poplar by *Pemphigus populitransversus*. The two species of *Chermes*, of one of which (*C. strobi*) I have no record other than Hutton's in the *Index Faunae Nov. Zeal.*, cover the twigs of pines with their flocculent covering secretion. *Aphis abietina* is killing spruce fir (*Abies*) in quite a wholesale manner in the Taranaki district, while *A. nerii* confines its attentions to oleander. A very recent introduction, *Aphis bakeri*, inhabits the flower-heads of red clover, where its honey-dew renders the seeds sticky and balls them up into refractory masses after harvesting.

FAMILY ALEURODIDAE—WHITE-FLIES.

Maskell described seven species from various native plants; but since then the family has been severely neglected.

FAMILY COCCIDAE.

It is not proposed to deal with this important family here at any great length. Maskell's collection has been carefully worked on in America for several years, and it is expected that the results will place the nomenclature and classification of the New Zealand scale insects on a satisfactory and up-to-date basis.

ANOPLURA.

While there can be no question as to the advisability of retaining this division as a separate order, the wide scope of this paper justifies the inclusion of the sucking-lice with the other sucking-insects of "incomplete" metamorphosis in the order Hemiptera. Mr. Elsdon Best informs me that the Maoris in pre-European days were infested with two well-differentiated species of lice, of which one was certainly *Pediculus humanus* Linn., while the other, from what I can ascertain of its habits, was probably *Phthirius pubis* Linn. Whether the head-louse, *Pediculus capitis* Nitzsch, was present and not recognized as a distinct kind is not certain.

The following list contains all the Anoplura at present recorded from New Zealand: *Echinophthirius microchir* Trouess. (on seal); *Pediculus capitis* Nitzsch, *P. humanus* Linn., and *Phthirius pubis* Linn. (on man); *Haematopinus asini* Linn. (on horse); *H. eurysternus* Nitzsch (on cattle); *H. suis* Linn. (on pigs, including wild individuals); *H. ovillus* Neumann (on sheep—short hair of face); *H. pedalis* Osborn (on sheep—short hair of legs); *H. ventricosus* Denny (on rabbit); *H. piliferus* Burmeister (on dog); *Linognathus vituli* Linn. (on cattle, particularly calves).

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A RING PROBLEM PECULIAR TO ELECTRICAL MACHINERY.

By R. Roberts.

This problem is described as peculiar to electrical machinery because in this class of machine-design it occurs most frequently. Scarcely any electrical machine of the rotating variety can be built without the use of a structure of this type. It occurs mainly in the form of end rings—*i.e.*, rings holding or clamping laminations and stampings together. The end-rings of the stators of induction motors and of alternating-current generators are pure examples of the structure. The problem occurs also in the end-rings of rotors and rotating armatures, and in the clamping vee-rings of the ordinarily constructed commutators, combined with centrifugal and expansion forces. Probably the most important example, because of the magnitude of the stress involved, is that of the end-ring, cap-ring, retaining-ring, or banding-ring, as it is variously termed, used to support the centrifugal forces of turbo-rotor end-windings.

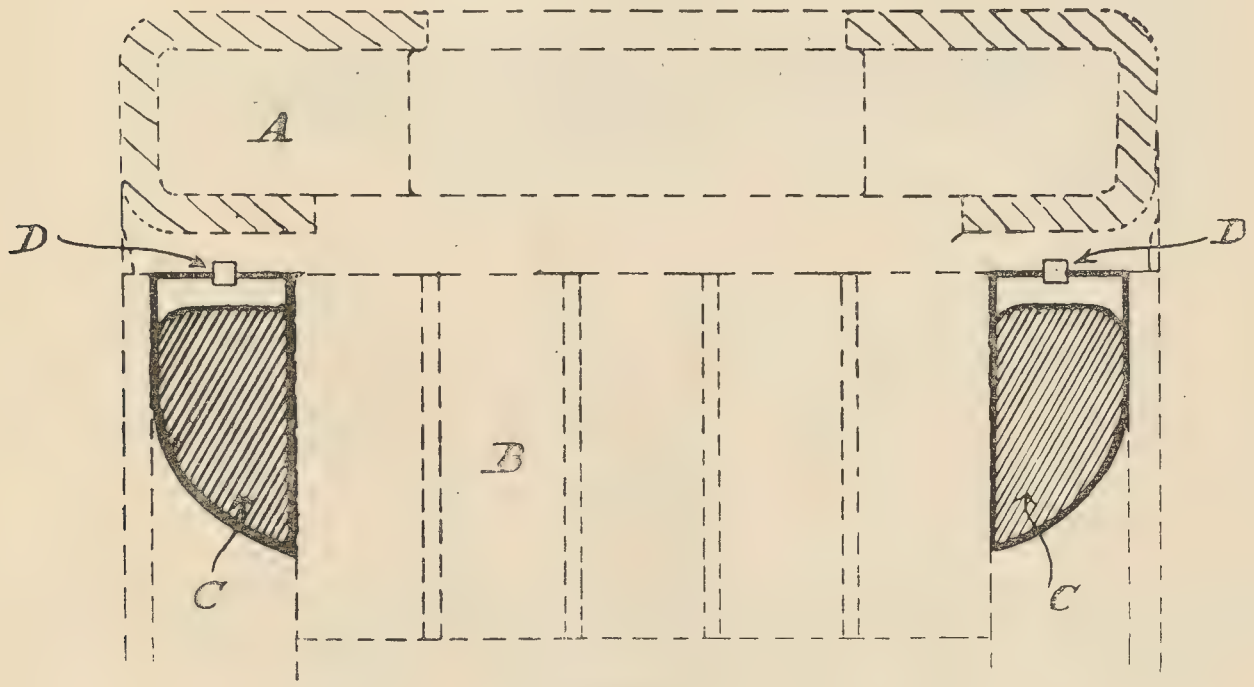


Fig. 1.

Fig. 1 shows the cross-section of a typical stator frame of an alternator or of a large induction motor. A is the cast-iron frame into which are built the sheet-steel laminations B, which are shown in section, and consist of rings or segments slotted on the internal periphery. These laminations are compressed and held in place by the cast-iron end-rings C, which are themselves secured against axial movement by the mild-steel keys D. These keys, probably $\frac{1}{2}$ in. square and 4 in. or 5 in. long, are placed at equal distances (usually not more than 12 in. apart) around the periphery, and are driven into place whilst the laminations and the end-rings are compressed together by bolts or by an hydraulic press. When the locking-keys D are finally in place the compressing-bolts are removed, and the reaction from the laminations, which should remain always in compression, reacts upon the end-rings C, which, restrained by the keys D, tend to turn "inside out." Were the laminations not held in compression the machine would be exceedingly noisy.

A commutator is an important part of the armature, or the revolving element of a direct-current generator or motor. It consists essentially of a number of copper segments insulated from one another and yet held together so as to present a smooth surface on the outer periphery. The brushes bear against this outer periphery and collect or transmit commuted current generated in the armature winding, which is connected to each segment of the commutator, and is also a part of the armature, which is the revolving portion of the machine.

Fig. 2 shows a half cross-section of a commutator. A are the copper segments and mica insulating segments, whose outer periphery is the brush-bearing surface, and which for satisfactory operation must always present a smooth and polished surface. During construction these segments are built up and clamped around the outer periphery in a suitable jig. Vee grooves are turned at the ends, in which, with the interposition of suitable insulation, the mild-steel vee-rings B are held by the bolts C. The rings

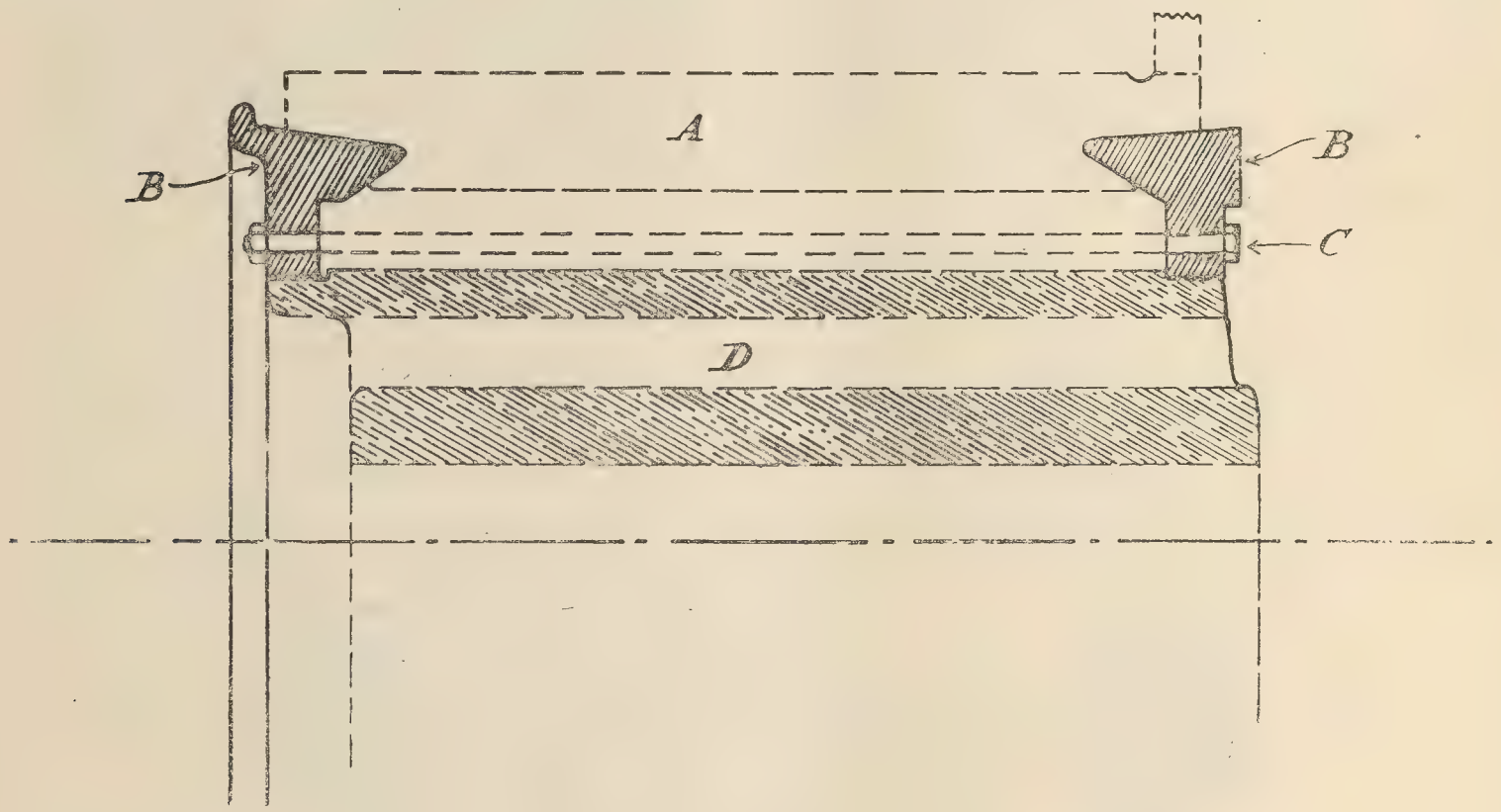


FIG. 2.

are mounted upon the cast-iron spider D, whilst the whole is carried upon the armature-shaft. In order that the outer periphery of the segments shall always be smooth and true, the forces exerted by the bolts must always exceed the axial components of the centrifugal forces of the segments. The heating of the periphery of the segments by friction to a higher temperature than that of other parts of the commutator complicates the design still further. However, under all conditions of standstill or full speed there must always be a tensile stress in the bolts C, and an axial compressive stress in the copper segments A. These stresses, therefore, produce moments acting upon the vee-rings B which tend to turn them inside out.

A turbo-rotor of modern design runs at peripheral speeds of 300 ft. to 400 ft. per second. The magnitude of the centrifugal forces created, the small diameters required for speeds of 3,000 and 3,600 revolutions per minute, and the necessity of having a unit which was capable of being balanced dynamically and of retaining this balance indefinitely produced a design which consists of the fewest and simplest of parts possible. Essentially it consists of a solid-steel forging about 2 ft. diameter, diminishing more or less suddenly at the two ends to journals about 5 in. diameter. The

central portion A in fig. 3 has axial slots (milled out of the solid) into which the windings are dropped and retained in position by metal keys. The ends of the windings B overhang the ends of the rotor core cylinder, and are restrained against movement due to centrifugal forces by cap-rings C_1 and C_2.

C_1 is a cap-ring designed so that the centre of gravity of the section coincides axially with the centre of gravity of the mass of end-windings.

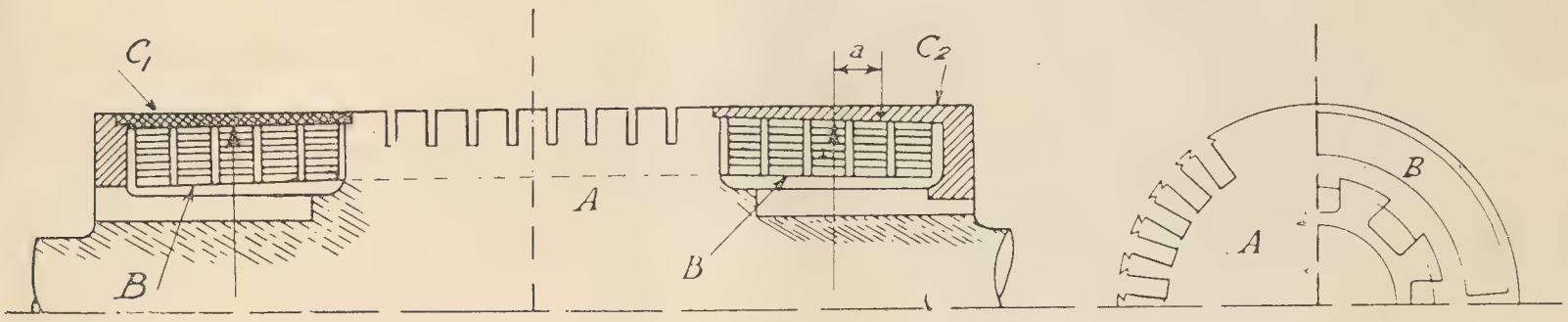


Fig. 3.

C_2 is a cap-ring of somewhat popular design, in which, however, the centre of gravity of section of the ring does not coincide with the centre of mass of the end-windings, but is separated from it by an axial distance *a*. It will readily be observed that C_2 has a greater section than C_1, and therefore, should the loads be correctly arranged, the stresses in C_2 would be less than those in C_1. But the proper arrangement of the loads in C_2, such that each portion of the section carried a load proportionate to its section, is an inherent impossibility of the design as shown. The design under load could be likened to a ring carrying a pure radial and symmetrical load but acted upon also by a moment equal to the total load multiplied by the

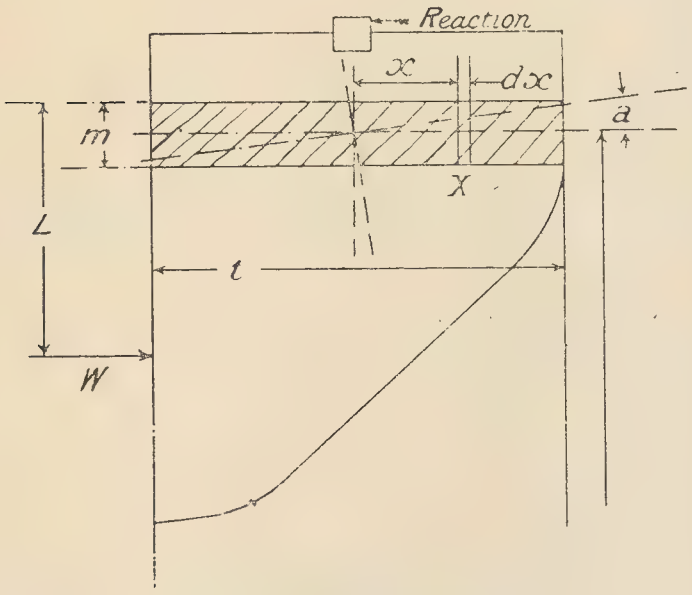


Fig. 4.

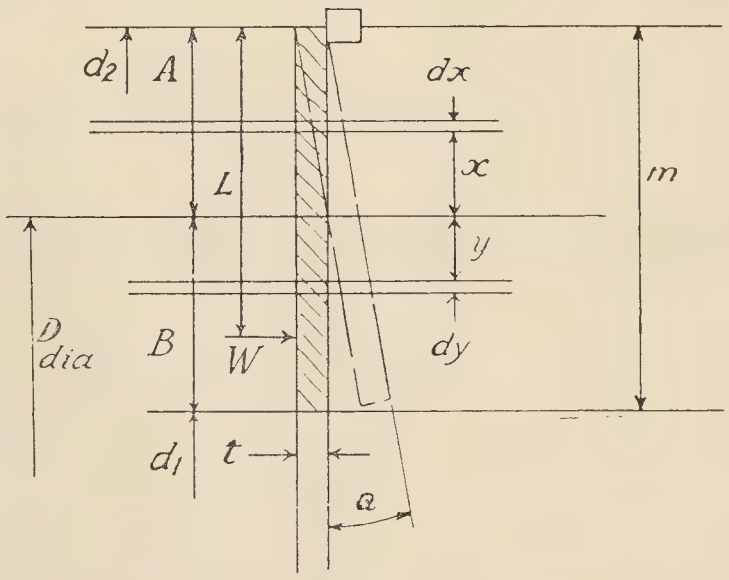


Fig. 5.

distance *a*, tending to turn the ring inside out. The recognition of the argument that the centre of gravity of the load should correspond with the centre of gravity of the ring section is seen to be of great importance when it is considered that the centrifugal-load stress in the ring is about equal to the stress created by the weight of the ring itself, and also that only very low factors of safety can be used. Factors of safety of 2 on the elastic limit of the material are not uncommon.

The problem investigated here is the calculation of stress and deflection of a simple ring when resisting moments and forces which tend to turn it inside out. By investigating the stresses and deflections for rings of three extreme sections a striking similarity of form and results may be shown,

from which a simple general set of rules may be adduced which can be applied to the majority of practical examples with fair accuracy.

Fig. 4 shows a ring of which the radial depth of section is small in comparison to the mean diameter and axial length.

Fig. 5 shows a ring of which the radial depth is large in comparison to the mean diameter and to the axial length.

Fig. 9 shows a ring of circular section, the section diameter of which is small in comparison to the mean diameter.

In fig. 4, which may be termed a cylinder-ring, let X be a point distant x in an axial direction from the centre of section.

Change in diameter of ring at this point, due to the action of a distributed moment as described, $= 2x \sin a$, where $a =$ angle of rotation of section about its neutral axis.

$$\text{Stress at this point} = \frac{2\mathrm{E}x \sin a}{\mathrm{D}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

$$\text{Radial pull for section } m\,dx = \frac{2\mathrm{E}x \sin a\ m\ dx\ 2\pi}{\mathrm{D}}$$

$$\text{Moment about centre of section} = \frac{4\pi\ m\ \mathrm{E} \sin a \times dx \cos a}{\mathrm{D}}$$

$$\text{Sum of moments for whole section} = 2\int_{o}^{\frac{t}{2}} \frac{4\pi\ m\ \mathrm{E} \sin a\ x^2\ dx \cos a}{\mathrm{D}}$$

$$= \frac{4\pi\ \mathrm{E} \sin a \cos a}{\mathrm{D}} \frac{mt^3}{12}$$

$$= \frac{4\pi\ \mathrm{EI}_1 \sin a \cos a}{\mathrm{D}} \quad \ldots\ldots\ldots\ldots (2)$$

$$\text{Sin } a \cos a = \frac{\mathrm{MD}}{4\pi\ \mathrm{EI}_1} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

By substituting the value of stress when $x = \frac{t}{2}$ in equation (1) we obtain

$$\text{Stress max.} = \frac{\mathrm{M}}{2\pi \frac{mt^2}{6} \cos a}$$

$$= \frac{\mathrm{M}}{2\pi\ \mathrm{Z} \cos a} \quad \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

where I_1 and Z_1 are the moments of inertia and modulus of the section about an axis normal to the major axis of the ring.

In fig. 5, where the axial thickness t is very small in comparison with the radial depth m, the position of the neutral axis will not necessarily coincide with the position of the mean of the ring diameters.

The increase in diameter of any point distant y from the neutral axis due to rotation of the section through an angle $a = 2y\ (1 - \cos a)$.

$$\text{The stress at this point} = \frac{2y\ (1 - \cos a)\ \mathrm{E}}{(\mathrm{D} - 2y)} \quad \ldots\ldots\ldots\ldots\ldots\ldots (5)$$

The radial pull due to the stress in section tdy

$$= 4\pi\ y \frac{(1 - \cos a)}{(\mathrm{D} - 2y)} \mathrm{E}\ tdy.$$

The moment about the neutral axis

$$= 4\pi y^2 \frac{(1 - \cos a)}{(D - 2y)} \sin a \, E \, t dy.$$

The sum of moments

$$\int_o^B M = \int_o^B 4\pi \sin a \, (1 - \cos a) \, Et \, \frac{y^2 \, dy}{(D - 2y)}$$

$$= - \frac{\pi \sin a \, (1 - \cos a) \, Et}{2} \{D^2 \log (D - 2B)$$

$$+ D^2 \log D + 2B^2 + 2DB\} \ldots\ldots\ldots\ldots (6)$$

Similarly for the outer part of the section,

$$\int_o^A M = \frac{\pi \sin a \, (1 - \cos a) \, Et}{2}$$

$$\{D^2 \log (D + 2A) - D^2 \log D$$

$$+ 2A^2 - 2DA\} \ldots\ldots\ldots (7)$$

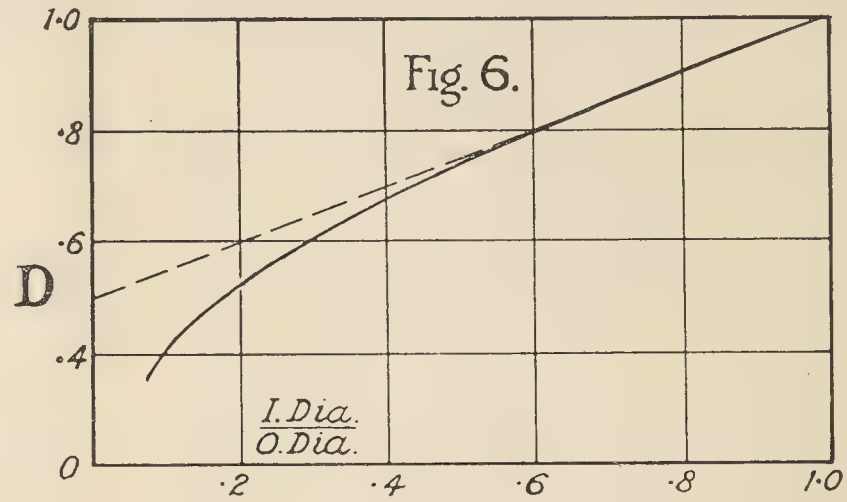
The total sum of moments due to stress in the ring section is the sum of equations (6) and (7). Since the moments in one part must equal the sum of moments in the other part, we can, by equating expressions (6) and (7), obtain values for D diameter of the neutral axis in the ring. Dividing both equations by

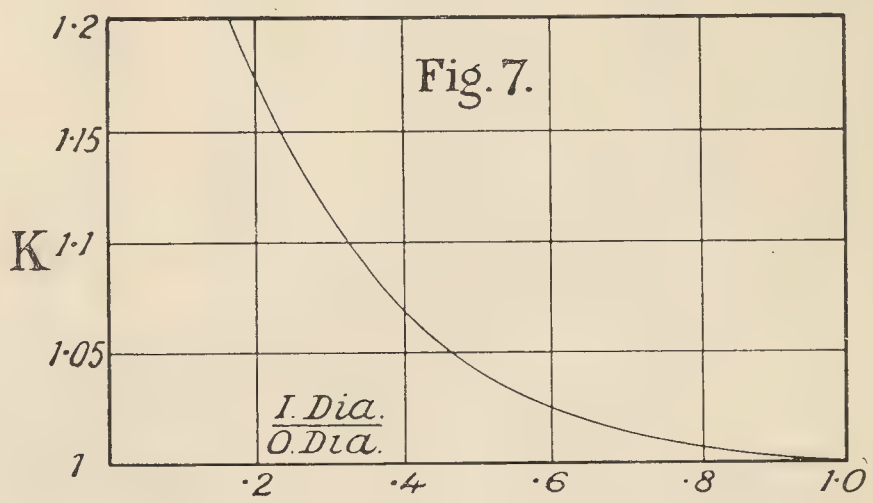
$$\frac{\pi \sin a \, (1 - \cos a) \, Et}{2}$$

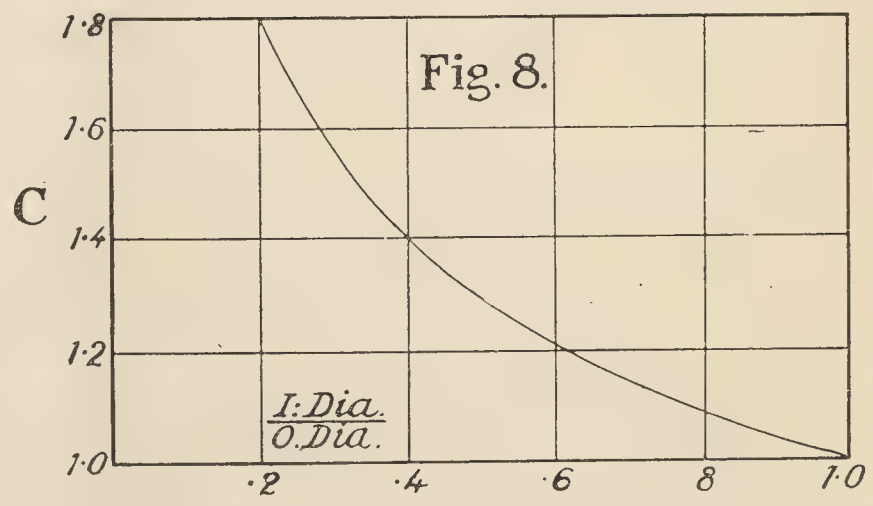
and substituting terms for A and B we obtain

$$\{D^2 \, (2 \log D - \log d_1 - \log d_2 - 3) + 2D \, (d_1 - d_2) - \tfrac{1}{2} (d_1^2 + d_2^2)\} = 0 \ldots\ldots (8)$$

From this values for D may be found for different ratios of d_1/d_2, as shown in fig. 6. The mean diameter is shown dotted and the neutral diameter full. It will be noticed that for the majority of cases met in practice, where the inside diameter is seldom less than half the outside diameter, the neutral diameter almost coincides with the mean diameter. In such a case







FIGS. 6, 7, 8.

$$M = \frac{\pi \sin a \, (1 - \cos a) \, E \, tm^3}{3D}$$

or

$$\text{Sin } a \, (1 - \cos a) = \frac{MD}{4\pi \, EI_2} \ldots\ldots\ldots\ldots\ldots (9)$$

where I_2 is the moment of inertia of the section about an axis parallel to the major axis of the ring.

Similarly, by combining equations (5) and (9) the maximum stress may be found :—

$$\text{Stress max.} = \frac{M}{2\pi Z_2 \sin a} \quad \ldots\ldots\ldots\ldots\ldots\ldots (10)$$

The effect of the neutral axis being displaced from the mean diameter is to reduce the angle of deflection under a particular load, and to increase the maximum stress, which occurs at the inner periphery. Fig. 7 is a curve for factor K, increasing the moment of inertia I_2 for different values of d_1/d_2 when the mean diameter is assumed to coincide with the position of the neutral axis. Similarly, fig. 8 is curve for a factor C, increasing the maximum stress above that which would be obtained were the neutral axis assumed to coincide with the position of the mean diameter.

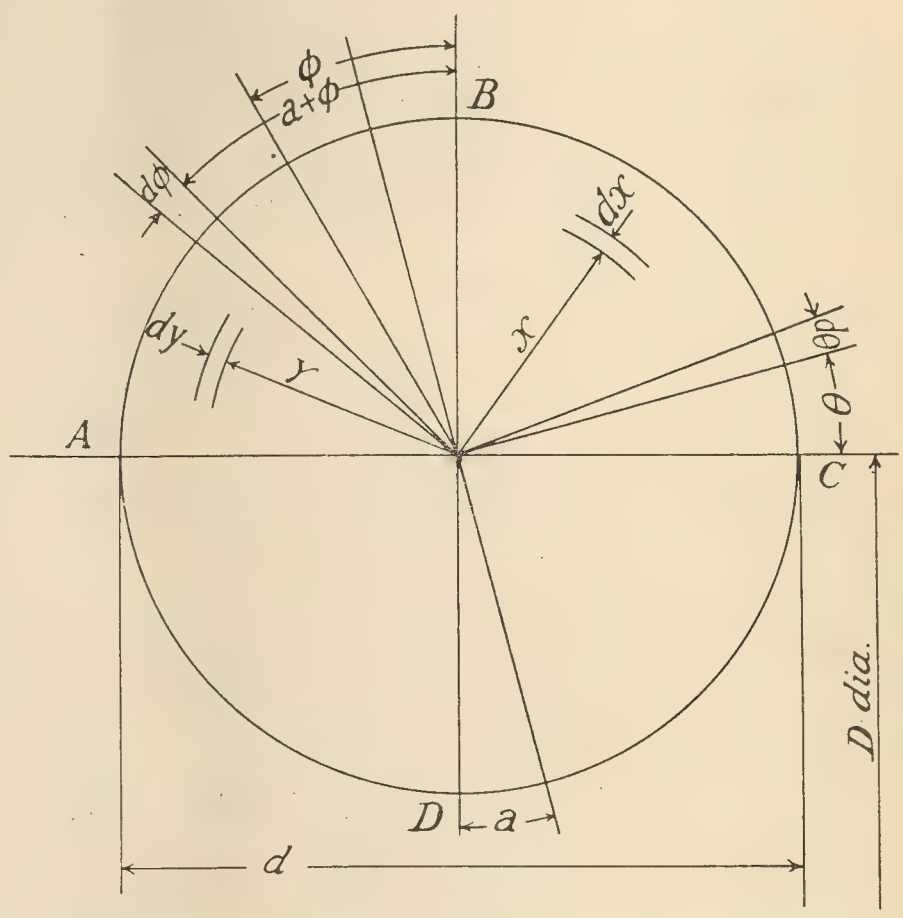


FIG. 9.

In fig. 9, which may be termed a circular section ring, any stress occurring in quadrant COB will not have the same effect for a definite angle of deflection as would a stress in quadrant DOC for an equal angle of deflection. For instance, were the angle of deflection 90°, all stresses in DOC would produce moments opposing such deflection, whilst the stresses in quadrant COB would not all have a similar effect. Quadrants COB and AOD will behave similarly in this respect, and quadrants DOC and BOA likewise similarly, but differently from quadrants COB and AOD.

Thus in quadrant COB, at any point X, increase in diameter

$$= 2x \{\sin (\theta + a) - \sin \theta\}.$$

Stress at this point due to deflection a

$$= \frac{2xE}{D} \{\sin (\theta + a) - \sin \theta\} \quad \ldots\ldots\ldots\ldots\ldots\ldots (11)$$

Radial pull due to this stress in the section $x\,dx\,d\theta = 4\pi\,x\,Ex\,\{\sin(\theta + a) - \sin\theta\}\,dx\,d\theta$. Moment about centre of section due to this pull $M = 4\pi\,E\,x^3\,dx \cos(\theta + a)\,\{\sin(\theta + a) - \sin\theta\}\,d\theta$. The sum moments in quadrant COB,

$$\int_{\substack{x=0\\ \theta=0}}^{\substack{x=\frac{d}{2}\\ \theta=\frac{\pi}{2}}} M = \int_{\substack{x=0\\ \theta=0}}^{\substack{x=\frac{d}{2}\\ \theta=\frac{\pi}{2}}} \frac{4\pi\,E}{D} x^3\,dx \cos(\theta + a)\,\{\sin(\theta + a) - \sin\theta\}\,d\theta$$

$$= \frac{\pi E d^4}{32D}\left\{\cos a\,(\cos a - 1) + \sin a\left(\frac{\pi}{2} - \sin a\right)\right\} \quad \ldots\ldots\ldots (12)$$

Similarly in quadrant BOA we obtain

$$\int_{\substack{y=0\\ \phi=0}}^{\substack{y=\frac{d}{2}\\ \phi=\frac{\pi}{2}}} \mathrm{M} = \int_{\substack{y=0\\ \phi=0}}^{\substack{y=\frac{d}{2}\\ \phi=\frac{\pi}{2}}} \frac{4\pi \mathrm{E}y^3}{\mathrm{D}}\, dy \sin(\phi + a)\{\cos a - \cos(\phi + a)\}\, d\theta$$

$$= \frac{\pi \mathrm{E}d^4}{32\mathrm{D}}\left\{\cos a(1 - \cos a) + \sin a\left(\frac{\pi}{2} + \sin a\right)\right\} \quad \ldots\ldots\ldots (13)$$

The moment for the total section is equal to twice the sum of expressions (12) and (13).

$$\mathrm{M} = \frac{2\pi\ \mathrm{E}d^4}{32\mathrm{D}}\left(\cos^2 a - \cos a + \frac{\pi}{2}\sin a - \sin^2 a + \cos a - \cos^2 a + \frac{\pi}{2}\sin a + \sin^2 a\right)$$

$$= \frac{2\pi\ \mathrm{E}d^4\ \pi \sin a}{32\mathrm{D}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (14)$$

$$\mathrm{Sin}\ a = \frac{\mathrm{MD}64}{4\pi\ \mathrm{E}\ \pi d^4} = \frac{\mathrm{MD}}{4\pi\ \mathrm{EI}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (15)$$

By substituting the value for the maximum stress from equation (11) in equation (14) we obtain

$$\text{Stress max.} = \frac{\mathrm{M}}{2\pi\ \mathrm{Z}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (16)$$

The stress is a maximum in the section when $x = \frac{d}{2}$ and when $\theta = 0$.

A general rule for the angle of deflection might be expected to take the form

$$\mathrm{Sin}\ a = \frac{\mathrm{MD}}{4\pi\ \mathrm{E}\ \{\mathrm{I}_1 \cos a + \mathrm{I}_2(1 - \cos a)\}}$$

This should be true for the circular ring case where $\mathrm{I}_1 = \mathrm{I}_2$, so that

$$\mathrm{Sin}\ a = \frac{\mathrm{MD}}{4\pi\ \mathrm{EI}\ \{\cos a(1 - \cos a)\}}$$

$$= \frac{\mathrm{MD}}{4\pi\ \mathrm{EI}},$$

showing an agreement that might justify us in assuming that such a formula would be correct for all sections.

The maximum values of stress for any section could not, however, be obtained in a similar way from equations (4) and (10), since the point of maximum stress is not necessarily that suggested from the minimum or maximum values of the modulus of an irregular section. In cases where it was necessary to obtain the absolute maximum stress values this might be done by finding first the angle of deflection and deducting the stress values at various points in the section for this deflection. In practice, however, when the deflection seldom exceeds 5°, values for stress might be found near enough for most practical purposes by the application of equation (4), modified as follows :—

$$\text{Stress max.} = \frac{\mathrm{M}}{2\pi\ \mathrm{Z}_1}.$$

Similarly for deflection,

$$\mathrm{Sin}\ a = \frac{\mathrm{MD}}{4\pi\ \mathrm{EI}_1}.$$

It will be found in practice that these expressions will give values for deflection and stress to within some 10 per cent. of the absolute values.

The experimental verification of these formulae is not difficult. Fig. 10 shows a ring approximately 5 in. diameter made of piano steel wire, ·018 in. diameter (26 S.W.G.), made by twisting the ends together. The projecting ends may now be bent through the ring and in position A it will be found to be unstable—*i.e.*, it will return to its original position either forwards or backwards through the ring. This simple experiment suggests the truth of equation (15), and is interesting as an example of a toggle spring. As is well known, toggles are usually produced by a spring and some mechanism, a lever or a cam. This spring needs no other mechanism, and may yet find a use as a spring for a snuff-box lid, where the application is self-evident.

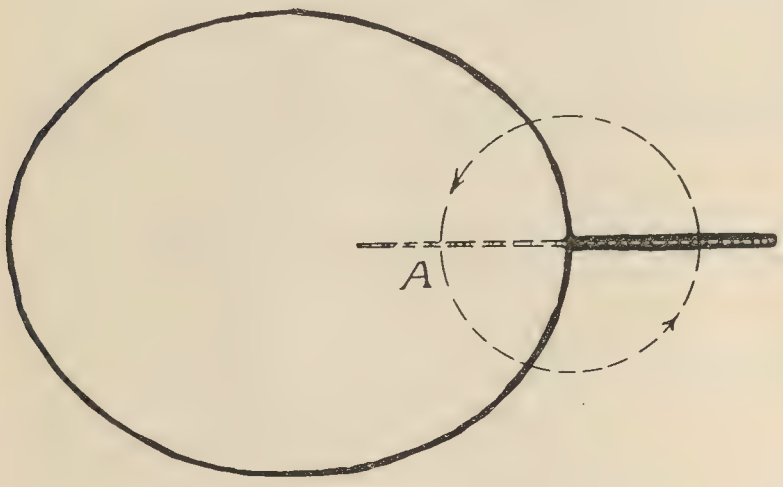


FIG. 10.

Another experiment is shown in fig. 11. A is a ring, 12 in. diameter, made of steel $\frac{1}{8}$ in. diameter. B are three cantilever arms to which is attached a small scale-pan C. Two points D, attached at points diametrically opposite, register the distortion or deflection of the ring upon any convenient scale (not shown). The length of the arms B is 5 in., and the weight in the scale-pan is 4 lb., so that the total applied moment is 20 lb.-in.

Applying equation (15), we find

$$\text{Sin } a = \frac{MD}{4\pi\ EI}$$

$$= \frac{20 \times 12}{4\pi\ 30\ 10^6\ \frac{\pi d^4}{64}}$$

$$= \cdot 0535 = \sin^{-1}\ 3^\circ\ 04'.$$

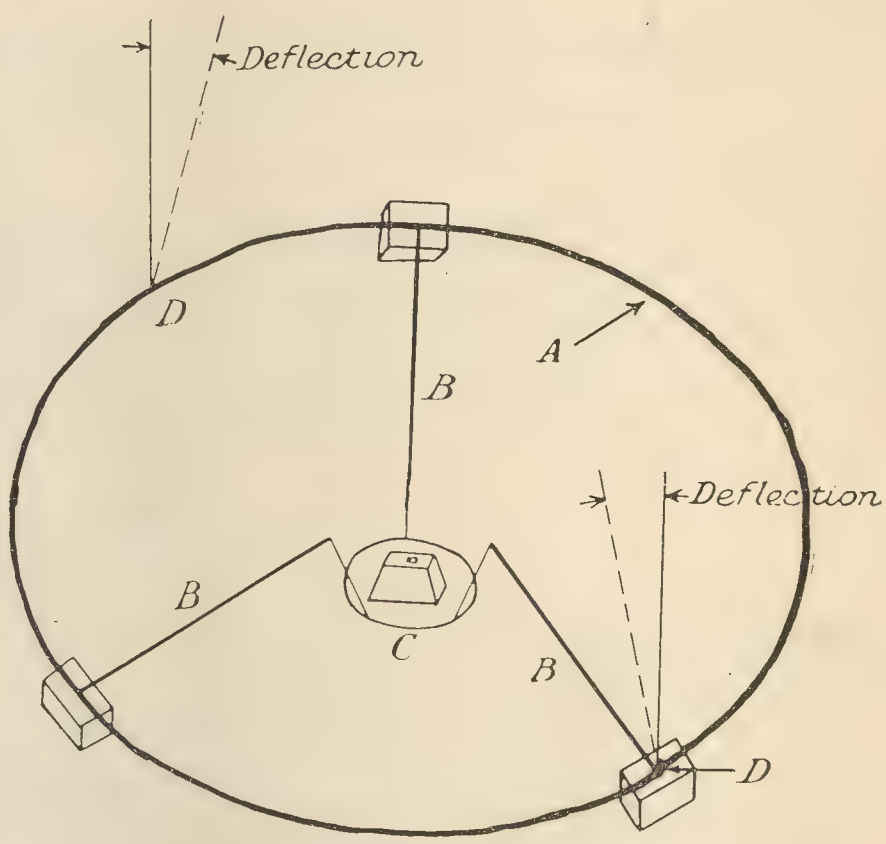


FIG. 11.

The actual measurements upon the scale when this experiment was made were 2° and 4°. The difference in the two readings is, of course, due to torsional shear in the ring section; and, since the amount of shear strain is proportional directly to the applied moment, the mean of these two readings will be the mean deflection of the ring. The actual deflection, had the moments been distributed evenly around the periphery instead of concentrated at three points, would have been 3° at any point. Within the scope and accuracy of the experiment these readings may be taken as a substantial corroboration of the theory.

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RAILWAY SIGNALLING.*

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N.Z. Railway Department.

RAILWAY signalling may be defined as the art whereby the movements of trains on a railway are controlled so that the traffic may be moved as rapidly as possible consistent with safety. It may be divided into distinct classes—(*a*) the electrical part, by which arrangements for and notification of the passage of traffic are made; and (*b*) the fixed signals by which the actual movements of trains are controlled.

Signalling enters very largely into the management of the railways throughout the world; and, when we consider the enormous number of trains the working of which is safely controlled by the various systems of signalling, it will readily be seen that signalling is a most important section of railway-management. As traffic increases new problems arise, many of which are successfully dealt with by improved arrangements in signalling. The signal engineer, therefore, has always to be prepared to grapple with any problem necessity may create, and to solve it in such a way that, whilst making provision for safety, he gives at the same time the greatest possible facilities for traffic-working.

The subject is one which at the present day covers so large a field that it cannot be dealt with on any but very broad lines in a paper of this description. The evolution of signalling has been one which has spread over a number of years, and a description of the evolution will probably convey a fairly clear idea of the general principles involved. We propose, therefore, to give a brief history of the growth of signalling practice, and then to describe in detail some of the more interesting forms of instruments in use at the present time.

When railways were first built they were worked without signals—the trains, which were few in number, were run according to time-table; but as traffic developed the necessity for some indication to control their movements became apparent. The original signal is the subject of many legends, and tradition has it that the first railway signal was a candle exhibited in the window of the stationmaster's office at Hartlepool to inform approaching trains that all was clear for them. The earliest known signal was used on the Stockton and Darlington Railways in 1825. It consisted of a bucket attached to a chain running over a pulley at the end of a jib on a post (fig. 1). When the bucket was lowered it indicated "Danger," and when hoisted "Clear." The bucket was perforated, and at night was filled with glowing coals.

About the year 1834 an approach to fixed signals was made on the Liverpool and Manchester Railways. On the top of a post, the height of an ordinary lamp-post, was placed, by means of a ladder, a red or white light. This signal was for night use only.

On the Great Western Railways, about 1837, a ball signal attached to a post was used. The ball when at the bottom of the post indicated "Danger," and when drawn up to the top "Safety," and a common

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*A paper read before the Technological Section of the Wellington Philosophical Society, 19th October, 1921.

stable-lantern was hooked on at night instead of the ball. In 1843 this signal gave place to one consisting of a cross-bar, 8 ft. long and 1 ft. wide, and a disc, 4 ft. diameter, fixed at right angles to the cross-bar (fig. 2). The presentation of the cross-bar to the driver indicated "Danger," and the disc "Safety."

On the opening of the Grand Junction and Liverpool and Manchester Railways, in 1838, they were furnished with signals which consisted of a circular or D-shaped board fixed on a spindle, with a handle to turn it through an arc of 90 degrees; a lamp showing a red or white light for night use was fixed on the same spindle. The disc turned towards the driver indicated "Danger," and when turned edgeways "Safety."

On the Newcastle and Carlisle Railways, in 1840, red disc signals were installed. The disc, 4 ft. in diameter, was fixed on a revolving pole with a handle to turn it.

About the year 1841 a most important step in the development of signals occurred, when Mr. C. H. Gregory, Resident Engineer, Croydon Railways,

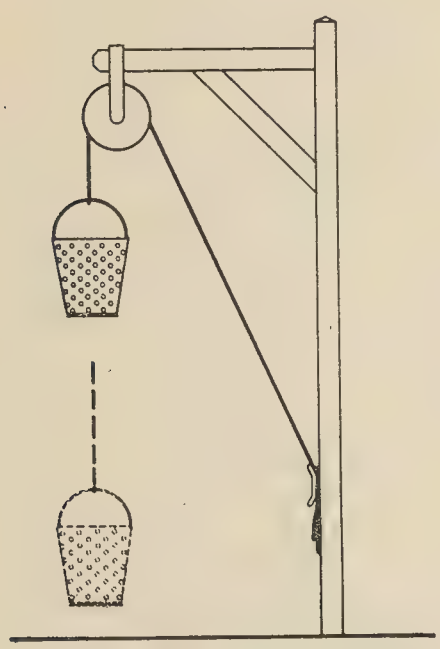
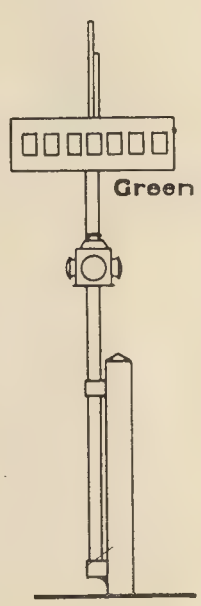


FIG. 1.



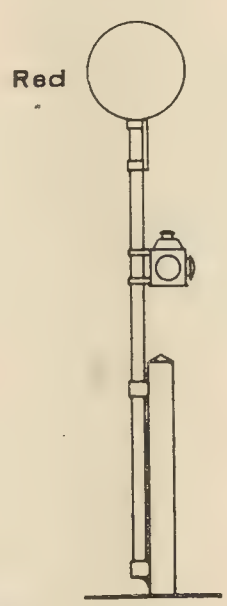


FIG. 2.

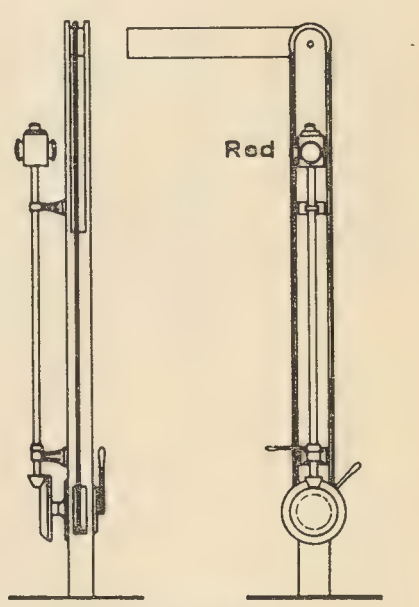


FIG. 3.

designed and erected at New Cross Station the first semaphore signal. This was a three-position signal indicating "Danger," "Caution," and "All right," the lights for night use being red, green, and white (fig. 3). The semaphore type of signal from this time onwards rapidly superseded all other types and became the universal railway fixed signal for running purposes; the disc type of signal was, however, retained for shunting purposes.

All signals were worked by pointsmen standing at the points until 1846, when what was termed a "distant" signal was introduced in Scotland at the junction of the Hawick Branch with the main line from Edinburgh to Berwick. These signals were fixed about 50 yards on either side of the pointsman's box, and were operated by a handle on the signal-post, the same way as all other types of signals up to this time. A pointsman, having to walk to and from these signals many times a day, arranged a wire to the handle of the signal, with a few railway chairs as a back balance-weight, so that he could pull the signal to "Safety" from his box, the balance-weight taking it back to "Danger."

This may be said to be the commencement of the system of working signals by levers fixed a distance away from them. The practice was found to be such a convenience that it soon became universally adopted, and

the Great Northern Railway, constructed soon after this, was completely equipped with signals operated in this way.

As traffic developed, the necessity for working a group of signals from a central point, so arranged as to make it impossible to give "Clear" signals for conflicting routes, became felt, and what may be termed the first attempt at interlocking of signals was an apparatus invented by Mr. Gregory in 1843 (fig. 4). This apparatus was fixed at the Bricklayers' Arms Junction, on the Brighton Railway. The chains from all the signals were gathered together into a stirrup-frame, and a sort of parallel motion was fixed to the frame between the stirrups in such a manner that the depression of any stirrup pushed the parallel motion so as to block one or more of the other stirrups, and thus it was impossible to give two signals which conflicted with one another at the same time. The pointsman worked the stirrups with his feet. By this means one man was enabled to work the various points and signals required at junctions; but, as it was possible for a signal

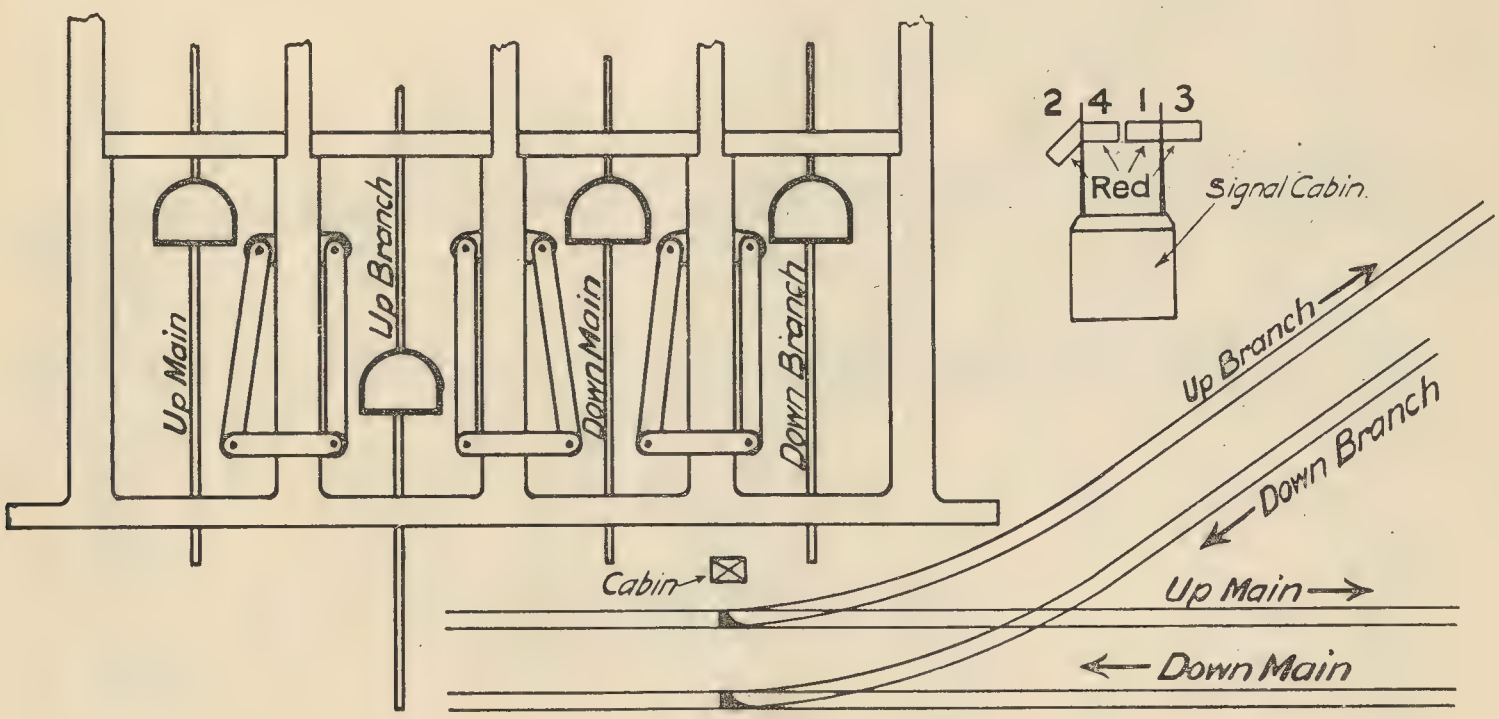


FIG. 4.

to be pulled off when a road was wrongly set, the necessity of interlocking the points, with the signals to prevent this, became apparent. The problem to be solved was to interlock the levers in such a way that a signal-lever governing a conflicting route should not be able to be moved.

After this numerous arrangements were devised for interlocking signals, also points and signals; but it was not until 1856—nine years afterwards—that the first complete interlocking system of points and signals was invented by Mr. Saxby. This apparatus was installed at the Bricklayers' Arms Junction, and consisted of eight signals and six pairs of points concentrated within a signal-cabin, all so governed and locked that it was impossible to give any signal which was contrary to the position of the points, and it was equally impossible to give any signal which would be in conflict with other signals. The means employed was to connect up the signals by wire, and the points by rodding, to the interlocking-apparatus, and operate them all from a central point—the equivalent to our present-day signal-cabin.

Mr. Saxby's invention was the foundation of the whole existing system of interlocking; and, although many different patents have since been taken out, the fundamental principle of Saxby's apparatus has not been altered, and the method employed is at the present time practically standard in all parts of the world.

After some serious accidents had occurred at facing-points, due to the points not properly closing, or to the signalman moving the lever when a train was travelling over the points, the necessity for additional security became manifest, and the facing-points lock and bar was invented in 1867, and was soon universally adopted. This apparatus is a bolt which locks the points and holds them secured after they have been moved by a lever. Attached to the bolt by means of cranks is a long bar fixed to the side of the rail, which is lifted when the bolt is operated, but cannot be moved during the passage of a train over the points, which are thus securely held until a train is clear (fig. 5).

With the development of traffic, accidents occurred through the breakage of the connections between the lever and the points, and the necessity again arose for further security. About 1877 an apparatus termed a "facing-point detector" was devised and came into general use. This apparatus is fixed alongside the points in the lead of wire operating the signal, the wire

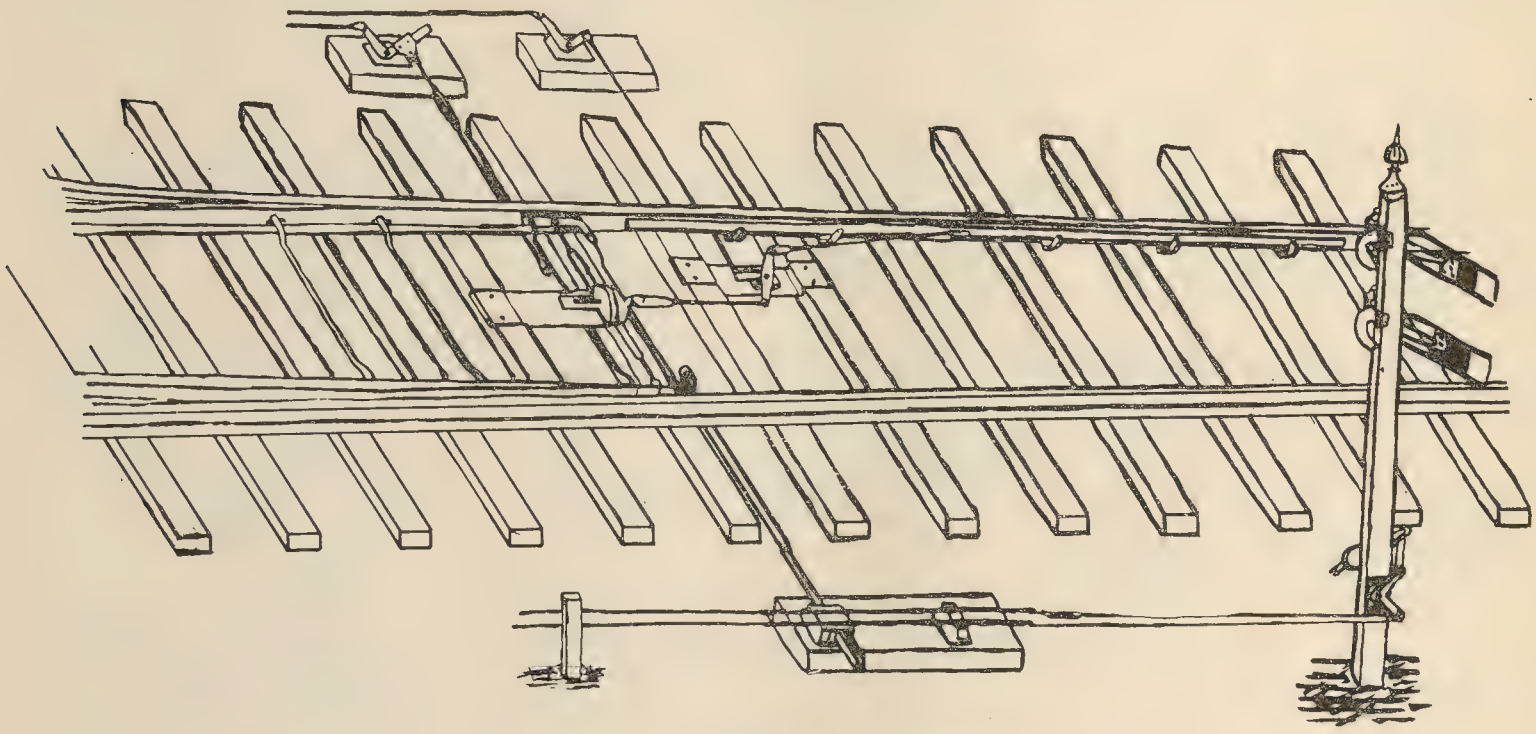


FIG. 5.

being attached to a plunger or lever, which works in a guide; a rod is taken from each blade of the points, and passes through the detector at right angles to the wire; in the rods are slotted holes, which must come exactly under the plunger or lever to enable it to move at all. In this way the signal cannot be pulled off unless both blades of the points are in their right position.

Figure 6 shows a modern interlocking-machine, consisting of levers, to which are attached the wires and rods working the signals. It will be noted that attached to each lever is a flat blade or sword-iron, which passes through channels in a locking-box. These sword-irons are notched as required, and small dies (locks) are moved in and out of the notches as the sword-irons are moved when the levers are pulled. The interlocking is effected by means of these dies, as it can be seen that if a lever is pulled and drives a die or lock into the notch of the sword-iron attached to another lever, that lever becomes locked until the first is replaced to normal. In the same way one lever can be made to release another, and the interlocking for a station-yard is built up by these methods. The designs for locking vary for every station, and it becomes a complicated piece of mechanism in many cases for big yards or junctions, often necessitating the design of "special locking" to obtain the desired security. The problem of the

safe working of yards has therefore been solved by the means described, and has mechanically, to some extent, reached finality.

The next problem, which arose simultaneously with that of interlocking, was the necessity for some means of regulating and controlling the passage of trains. This did not apply to yards or junctions, but had to deal with trains following each other between stations, or opposing each other on single line. In the case of double lines, the first system used in order to ensure a safe interval between trains was what was known as the "time-interval system"—that is, after one train had passed a point a second one could not be signalled to follow until a certain time had elapsed. The time interval was usually something of the order of five minutes.

The control of the trains at the timing-points was effected by having a red and a green board fixed on a pole at right angles to and one below

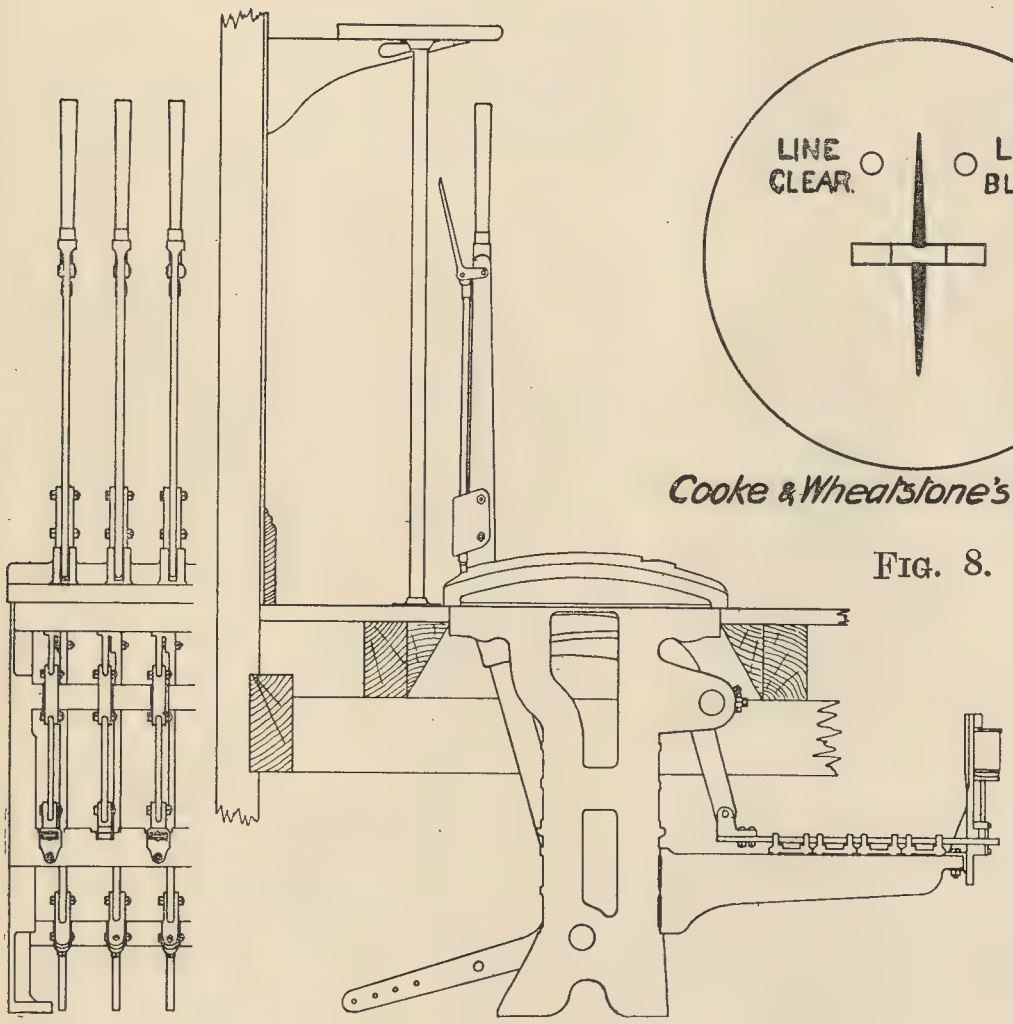
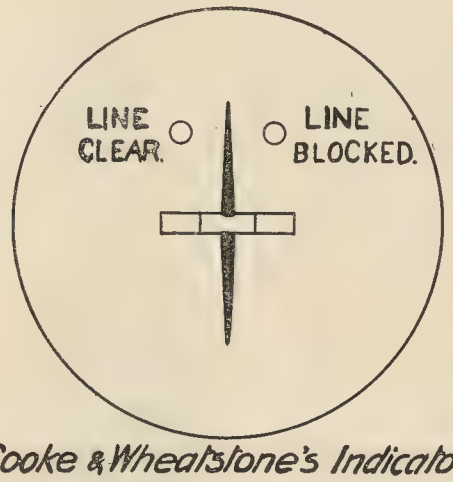


FIG. 6.



Cooke & Wheatstone's Indicator

FIG. 8.

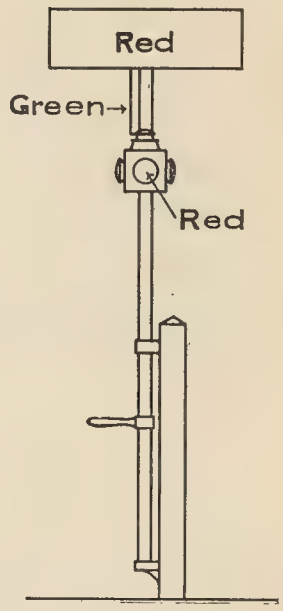


FIG. 7.

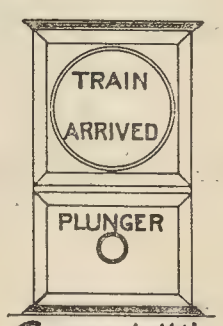
the other (fig. 7). Immediately the first train passed the red board was turned to face the following train, the green board being on end or parallel to the line, and after five minutes the red board was turned edgeways and the green board shown. This arrangement was used for some time, but with the advent of the telegraph it became possible to ascertain the arrival of a train at a station before despatching a second train, and the system known as the "space-interval system" came into use. Briefly, a "space-interval system" consists of maintaining a certain space between trains independently of any time interval. An objection to the latter system arose owing to the length of sections, which at that time was governed by the distance apart of the various stations, and the time that had correspondingly to elapse between the despatch of following trains became a serious matter with the increase of traffic. This objection could only be obviated by the building of block stations at frequent intervals, the intervals depending on the density of the traffic required to be run over the various sections. With the installation of these block stations the block system

was an accomplished fact in principle, and what may be termed the inception of the "block system" was brought into use between Paddington, West Drayton, and Hanwell, on the Great Western Railways, at the instance of Cooke and Wheatstone, in December, 1839. Two years later the same inventors introduced independent instruments for the signalling of trains, which provided a means of communicating instructions for the working of traffic by a pre-arranged code of electric-bell signals, and by indicators (fig. 8) showed the condition of the line at all times. Therefore to Messrs. Cooke and Wheatstone belongs the honour of having originated the "block system" of train signalling.

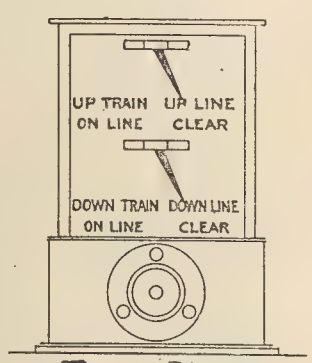
Numerous types of apparatus followed. Among the most notable was Tyer's, brought out about 1851; Clark's, in 1853; and W. H. Preece's, in 1862. Figures 9, 10, and 11 show several early forms of block instruments by different inventors.

In the early "seventies" block working in some form was firmly established on the main routes of all the principal railways. As complete dependence was placed upon the human element in regard to the messages stating that a train had cleared a certain section, accidents became frequent

Preece's Apparatus.



Spagnoletti's Indicator.



Tyer's Block Indicator.

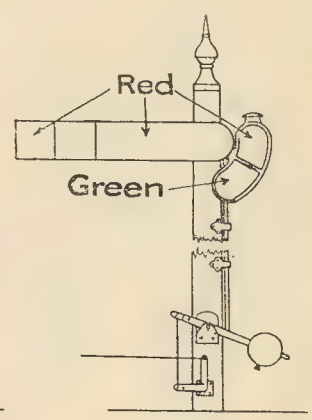


FIG. 9. FIG. 10. FIG. 11. FIG. 12.

with the growth of traffic, particularly with the time-interval system. The principal method in use for working single lines was by "pilotman," who accompanied each train passing over a section, and further relief was found in this man issuing tickets permitting trains to follow one another. This system worked satisfactorily for a while, but about 1870 a train-staff was designed to take the place of the pilotman. Each staff had two boxes, one at each end of the section; and, as the key of the boxes was the staff itself, tickets could only be obtained from that end where the staff was. This system of working single lines was generally in use for a number of years.

In 1878 Mr. Edward Tyer invented the electric train-tablet apparatus, which was first installed on the Lockerbie and Lochmaben Branch of the Caledonian Railways. This system was a great advance on the staff and ticket, being a combination of the absolute block system with the train-staff and ticket system, with this very important addition: that, with the "tablet," trains may be admitted on to a section of single line from either end. With the train-staff a train could only enter from the end where the staff was.

In 1889 a rival system appeared, known as the Webb-Thompson electric staff. This system, in principle, is the same as the tablet, the difference being the form of the token, a staff somewhat similar to that used with the staff and ticket being used, whereas with the tablet system the token takes the form of a round disc. Very great improvements have been made in

these systems since they were first invented, and both are very largely used to-day for single-line working throughout the railway world.

On the New Zealand railways the Tyer's tablet system, with the latest design of instrument, is used for single-line working, over nine hundred instruments being now in use. With the tablet system an instrument is provided at each end cf the block section on a single line, and arranged so that by the co-operation of the men at each end of the section a tablet can be taken out of the instrument at one end and a visual indication of the operation recorded. This having been done, the instruments become locked, and no further tablets can be obtained until the one removed has been replaced in the instrument at either end of the section. The tablet is carried by the driver of a train, and forms his authority to proceed into the block. As not more than one tablet can be obtained at a time, the safety of a train on a single line is assured.

Owing to numerous accidents to the station staff and enginemen occurring through the hand-exchanging of the tablet or staff, exchanging-apparatus was devised. The original exchanging-apparatus was invented by Mr. James Manson, of the Great North of Scotland Railways, somewhere about 1887. In 1907 an order was issued by the British Board of Trade that exchanging-apparatus must be provided, or a speed-limit of ten miles per hour must be enforced.

The growth of safety appliances in regard to the block system has been based on the principle that a train must arrive at a station before permission can be given for a second train to leave the station in the rear, and numerous systems have been invented from time to time which have had for their main object the elimination, as far as possible, of the human element in dealing with the safe working of trains. Many schemes have been developed, the main features in all systems being that a record of the various operations carried out should be indicated, and that the indications should remain until they are wiped out by the concurrence of the men at both ends of the section. The indications involved are—(1) Permission for a train to approach being asked for; (2) permission for a train to approach being given; (3) the presence of a train on the block; (4) the block is clear.

The actual wording of these various indications differs to some extent on the different kinds of instruments, but basically the descriptions of the indications given cover the principles worked to. Most of the earliest block instruments consisted of a means of giving the indications referred to, together with a tapper or plunger for the purpose of signalling by means of bell signals. The later developments, such as the Sykes lock-and-block system for double lines, in addition to indicating the state of the block, also lock the various routes over which permission has been given for approach, and lock the signals until the actual releases have been given or received. This was a great advance of the purely visual old type of block instrument, and for dense traffic some form of this principle became a necessity. An adaptation of the Sykes block instrument, manufactured by Messrs. McKenzie and Holland, is used in this country on the railways on double-line sections in the metropolitan areas. It may be mentioned, before leaving the subject, that the final release of these instruments is effected by the passage of the train itself over a treadle contact fixed on the rail, so that the signalling that the block is clear is out of the hands of the signalman entirely. There are several other systems somewhat on similar lines to the Sykes lock-and-block, which were developed by Tyer, Spagnoletti, and others, but the

Sykes instrument is the one which is used to a much larger extent than any of the others.

A purely visual instrument for double-line working was developed by Tyer. This is used on many lines to a large extent, particularly where the traffic is not very dense.

In 1889 an Act of Parliament was passed in England making the adoption of the block system and the interlocking of points and signals compulsory, and since the passing of this Act no railway can be opened in Great Britain until equipped with the block system and signals properly interlocked.

The various apparatus described may be regarded as the ordinary manual signalling and interlocking system. This brings us to the important subject of the operation of points and signals by power. The advantages of power-operated systems over manual are many and great. One signal-box can be used where two or three manual boxes would be necessary, thus effecting a saving in the number of signalmen required; the signalman's labours are reduced to a minimum; the yard is kept clear of rodding and wires, making it safer for shunters, &c.; and the points and signals can be operated at a much greater distance.

The first power signalling plant was an all-air one designed by Mr. George Westinghouse, and installed at Bound Brook, on the Philadelphia and Reading Railway of New Jersey, in 1884.

We now propose to give a few brief descriptions of the principal power systems in use:—

The Hydraulic-power System.—In this system the points and signals are operated by cylinders actuated by water-pressure. The system was invented by the Italian firm of Bianchi-Servettz in 1886, and is largely used in Italy, southern France, Spain, and also in Russia. A fine plant of this system is in use in South Africa, at Cape Town.

The Electro-mechanical System.—In this system all the signals are worked electrically, and the points by the usual mechanical methods. The system was invented by Mr. W. R. Sykes, and first installed at St. Enoch's Station, Glasgow, about the year 1900.

The Low-pressure Pneumatic System.—This is an all-air system in which not only the points and signal-motors but all the controlling valves are operated by compressed air, and was first designed by Mr. J. W. Thomas, of the Nashville, Chattanooga, and St. Louis Railway, and was fixed in Nashville in 1897.

The Electric Pneumatic System.—In this system the points and signals are operated by compressed air acting through motors consisting of small cylinders and valves. The valves controlling the admission and exhaust of air to and from the motors are electrically operated. The movements of all points, signals, &c., are electrically indicated in the locking-frame in the signal-box in such a way that should any movement be partially or wholly prevented the lever and all the others dependent on it are locked up, and so cannot be moved until the cause of the obstruction is removed. This system has been installed in New Zealand at Dunedin, and consists of two signal-boxes with a total of sixty-eight working-levers, thirty-five in one box and thirty-three in the other. Under the mechanical system of interlocking the Dunedin Station would have required three signal-boxes with a total of 150 levers.

The All-electric System.—In this system, as the name implies, the power employed is solely electricity. The system was first introduced in America in 1893, and was known as the Taylor system. The largest electrical-

signalling installation in the world is at the Grand Central Terminal Station of the New York Central and Hudson River Railway. The suburban lever machine has 400 levers, and the express lever machine has 362 levers. One man is assigned to the working of each forty levers. At the busiest period forty-six trains are dealt with on two tracks in the same direction in thirty-nine minutes.

The first electric signal was invented by Mr. W. R. Sykes in 1875, and installed at the Penge Tunnel, on the London, Chatham, and Dover Railway.

An interesting development in connection with power-signalling installations is the illuminated diagram in the signal-box. This takes the form of a diagram of the lines, with a glass front, behind which are electric lamps grouped in sections corresponding to the various track sections of the installation. The lamps are switched in and out by means of the track relays concerned, and the diagram thus gives a visible indication of the state of the track and position of the trains within the control of the signalman. By means of an illuminated diagram it is possible for a signalman at an interlocking plant to carry out the whole of the required operations without obtaining any outside view of the trains or track under his control. In some of the interlocking plants on the underground railways in London and New York the signalman handles the whole of the traffic without ever obtaining a sight of a train.

It will be appreciated that the block systems described, all being manually operated, necessitate men being placed at each block post or station, and also that, as only one train can be in any block at one time, the length of a block to a large extent determines the capacity of the line for traffic. In order, therefore, to accommodate heavy traffic it becomes necessary to shorten up the block sections, and this in every case, with a manually operated block system, means that more men must be employed, with a corresponding increase in expenditure. Again, there is no particular advantage gained by shortening blocks beyond a certain point, as the actual operations of the instrument take a certain length of time, and, as the running-time of trains through a very short section is so small, the operations of the block itself cause delay. This position of affairs actually arose in many cases on railways at metropolitan termini, and the only remedy at the time was to provide additional lines leading into the terminus.

The problem of how to provide for dense traffic without involving very great expenditure is one which has been receiving the attention of railway men for a number of years, and a solution has been found which promises to overcome a great deal of the difficulty to a very large extent, and that is the installation of automatic signals controlled by means of the track circuit. The development of the track circuit itself commenced a good number of years ago, in 1864, in England, when Mr. W. R. Sykes installed an experimental track circuit near London. A patent was also taken out about the same time in America, but it was not until the early " eighties " that any advance was made. Since that time track circuit has developed very rapidly for a number of years in America, and to a very large extent during recent times in England and other countries, until at the present time there are many thousands of miles of railway entirely controlled by means of it.

Briefly, the track circuit is an insulated section of the rails of the permanent-way, one end of which is fed from a battery or A.C. supply, with a relay connected at the other end. The automatic signals, which are operated either electrically, by means of air, or by carbonic-acid gas,

are controlled electrically through the contacts of the track relay. As long as there is no train on the section or track circuit the relay is energized and the automatic signals are at "Clear"; but immediately a train enters the section it short-circuits the track-circuit supply and de-energizes the relay, which places the signals at "Danger."

By the application of this system the presence of the train itself controls the signals, and therefore if a track circuit is installed along a line it can be divided into as many sections as required, the length of the sections being determined by the safe braking-distance of a train. With steam-trains of varying weights this distance is rather a variable quantity, so that sections are usually made longer than is actually essential in order to allow a certain amount of margin for variation of the braking-distance. With electric trains, however, the braking-distance can be fixed very definitely, and the sections made of very definite length without the same allowance that is required for steam traffic. With the installation of complete track-circuiting the manual block is no longer required, and consequently no staff is needed at purely block posts, signalmen being required only where it is necessary to operate points at junctions or yards. The details of the system are involved and complicated, and there is not time for these to be gone into on this occasion.

The last development of signalling with track-circuiting and automatic signals has to a large extent amalgamated what were originally two distinct phases, interlocking and block working. It has also in many cases increased the capacity of the line to such an extent by its installation that the necessity for additional lines being built to accommodate traffic has been rendered unnecessary. In regard to semaphore signals themselves, most people are familiar with the signal which is installed on the New Zealand railways (fig. 12). It is mechanically worked by means of a wire, and indicates "Stop" when in the horizontal position, and "Clear" when it drops to 45° to 60° from the horizontal, the night indications being red and green.

Automatic signals of the latest design, however, give three indications, and move in the upper left-hand quadrant in place of the lower quadrant. The indications are "Stop" when horizontal, "Proceed under caution" when at 45° upwards, and "Proceed at speed" when at 90° upwards. The lights at night are red, yellow, and green respectively.

The advantage of the three-indications signal is that the driver is given much further information than with a signal which merely says "Stop" or "Proceed," as he is told with the three-indications signal to "Stop," "Proceed, prepared to stop at the next signal," or "Proceed; the next signal is at 'Caution' or 'Clear.'" In mechanical signalling the distant signal, which is the outermost signal when approaching a station, gives the driver warning of the position of the "Stop" signals ahead. It has a fish-tailed arm, and may be passed at "Clear" or at "Danger." It will therefore be appreciated that, whereas in mechanical signalling it is only when approaching a station that a driver receives any cautionary signal, with automatic signalling every signal gives him this information in regard to the signal next ahead. Automatic signalling increases the carrying-capacity of the line, and also reduces working-expenses, as less signalmen are required.

It may here be mentioned that the latest alternating-current system of electric automatic signalling with upper-quadrant three-position normally "Clear" signals is now being installed on the New Zealand railways between Wellington and Lower Hutt for double-line working, and between Lower Hutt and Upper Hutt for single-line working.

The single-line signalling differs essentially from double-line in that it must afford protection for train-movements in either direction, whereas double-line signalling presupposes all train-movements to take place only in a predetermined direction on a given section of line. The system being adopted is what is known as the "absolute permissive system"—that is to say, for opposing trains absolute block is provided from crossing-place to crossing-place, while for following trains the blocks are subdivided into sections, which can be as short as required. The system will be normal "Clear" signals, with the exception of the block signals (*i.e.*, the signals governing the entry into sections between crossing-places). These signals will be normal "Danger," and will clear as a driver approaches them if the section ahead is clear.

In regard to the reliability of the automatic signalling the following statement has been published: "On the Metropolitan District Railway, England, the average failures have been stated at 1 in 315,000 movements, and on the New York subway only 1 in 3,359,167 movements." From

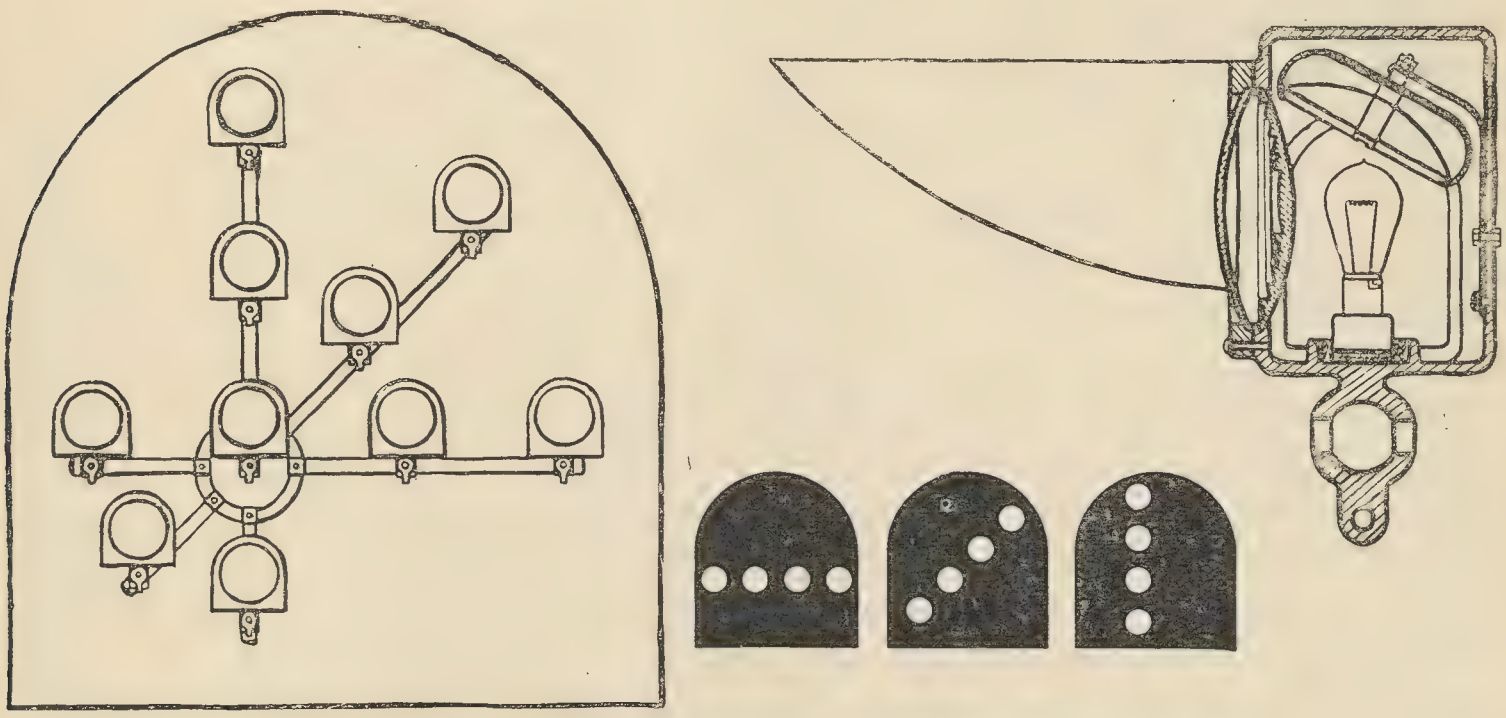


FIG. 13.

this it will be seen that the system has reached a very high state of efficiency.

Automatic signalling is so designed that the failure of any part of the apparatus shall be on the side of safety to the traffic, and a failure on any section at once puts the signals for that section to "Danger."

In connection with the single-line working, a train-control system is included for the purpose of expediting the control of traffic in the event of crossing trains not meeting at the scheduled crossing-place. The system will consist of a special telephone circuit with a telephone fixed on each starting or block signal (which is the signal controlling the entrance to the section ahead), and will be in direct communication with a traffic-control officer at the control station.

A most interesting development which is taking place in connection with signalling is that made possible by the introduction of what is known as the "beam light" signal (fig. 13). This is an illuminated sign by which the form aspects of the ordinary semaphore-indications are given, both by day and night, by means of a series of lights, in a manner similar to the illuminated signs used for advertising purposes. One of the chief problems is, of course, to produce an illumination which shall be visible in bright sunlight as well as by night. This is being solved by the use of lamps of

comparatively low candle-power in conjunction with the most accurately adjusted reflectors and lenses, also the provision of hoods over each unit.

By the use of signals given exclusively by means of a series of lamps the whole of the difficulties in connection with the motors and mechanisms now used for operating semaphore-arms would disappear, and maintenance costs should be reduced to the matter of current-consumption and renewal of lamps. In this connection it may be mentioned that in underground electric railways the use of semaphore has been entirely discontinued, the indications being given entirely by coloured lamps, the various colours being switched in as required under exactly the same conditions as a semaphore would work. For underground work the sunlight does not have to be contended with.

The " beam " or position light signal is the joint invention of Mr. A. H. Rudd, Signal Engineer of the Pennsylvania Railway, America, and Dr. William Churchill, of the Corning Glass-works. Several trial installations have been laid down, and the results are being looked forward to with very great interest.

The next stage in the evolution of signalling is in the direction of locomotive-cab signals and train-stops. From the description which has been given of the various systems of signalling it has been made clear that a signal for a train to proceed cannot be given until the conditions are such as to make this safe. The efficiency of the arrangement in preventing collisions is, however, still ultimately dependent on the driver obeying the signal so displayed. This introduces the question of automatic train-stops. At the present time very little progress has been made in the adoption of automatic train-stops on steam railways, and it is usually considered that to take the control out of the hands of the driver and automatically to apply the brakes of trains of various weights and composition, and travelling at various speeds, might be attended with serious results. Upon electric railways, the conditions being different, automatic train-stops are generally used. These work in conjunction with the signals, and are set so as to trip the valve of the continuous brake when the signal is at " Danger."

Allied with the question of train-stops is the question of providing a reproduction of the outdoor signals within the driver's cab. This is usually done by audible means, and numerous schemes have been devised for this purpose, but none have yet been generally adopted. In view of the fact that so much has been done to safeguard the operations as between the signalman and the driver, it appears only logical that the next step should be to afford a similar safeguard as between the driver and the signal, and considerable development in this respect may be looked for in the future. At the present time there are two special Commissions—one in England and one in America—investigating the whole question of the control of trains by automatic train-stops, and as a result some scheme may be evolved that can be universally applied.

As long as trains run on railroads, so long will accidents occur. Every time a train runs a dangerous potentiality is introduced, and as long as train-movements are made under the direction of fallible humans, so long will the chances of accidents continue; therefore, in signalling, the one aim is, and always must be, to reduce them to a minimum. The remarkable immunity from serious accidents obtaining throughout the railway world, considering the enormous amount of traffic handled, is largely due to efficient means of signalling.

The foregoing briefly covers the history of the evolution of signalling from its beginning to the present day.

DYNAMIC SYMMETRY.

A Mathematical Analysis of Beauty of Form.*

By S. H. JENKINSON.

THE objective of this paper is to explain in a few well-chosen words the secret of that mysterious and hitherto inscrutable fascination which beauty exercises over the human mind. *Mutatis mutandis*, this was the introduction to a discourse on "Music" given some years ago by the eloquent Haweis, and will serve very well on this occasion.

It will no doubt appear strange to many that the "low cunning" that forms the distinguishing feature of mathematics can be applied to such a sensuous and intangible appeal as that of beauty, while others will feel that it is a degradation of the noble science of numbers to apply it to the "base utilitarian purposes" of art; but both these attitudes arise from one common misconception. Everything in nature is capable of mathematical expression if the truth can only be arrived at, since mathematics simply describes, but does not attempt to explain, those laws according to which all natural phenomena develop or exist. A mathematical expression does not in any way govern or regulate the course of any natural event; it only describes in generalized arithmetical terms the average quantity, variation, or duration of any natural function or quality. If, for instance, it were found that those female figures which appeal most insistently to the average male were those whose height approached most closely to four times their breadth, then we could say that the law of female beauty or attraction could be mathematically expressed as $H = 4B$. It will be obvious that this expression makes no attempt at explanation. Or if it were found—and this time there appears to be some grounds for the assumption—that the intelligence of the average male increased steadily from the age of two to the age of forty-five, and afterwards declined at the same steady rate, then we could say that the law of male intelligence was $I = k[43 \pm (A - 45)]$. It will be noticed that this expression clearly states that the average male approximates zero intelligence at the ages of two and eighty-eight, but it offers no explanation of the fact (if fact it be); and, further, it does not assert that every male is intelligent between the ages of two and eighty-eight. It merely pretends to be a shorthand expression of the conclusion arrived at by the observational student of psychology concerning the average mentality of his male friends. Mathematics, you will now understand, is the handmaid, and not the *alma mater*, of science. and there can be no objection to using it to express the conclusions recently arrived at by close observers of the beautiful in decorative art.

As yet the laws of design have been formulated for that division only of art which deals with form and shape. A Scotch scientist† (and I trust no one will assert that these are contradictory terms) attempted to extend

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*A paper read before the Wellington Philosophical Society, 25th May, 1921. The author has found quotation marks inadequate to properly express the fact that this paper is largely based on JAY HAMBIDGE, *Dynamic Symmetry* (Yale University Press), 1920, and T. A. COOK, *The Curves of Life* (Constable), 1914.

† David Hay.

design into the domain of music, but without any success; and so far no one has been bold enough to attempt the reduction of colour schemes in painting and decorative art to formalized design with its fundamental mathematical basis. It has, however, long been understood that the ancient Egyptians and Hindus, and, to a much greater extent, the ancient Greeks, based the design of their architecture, drawings, sculpture, and pottery upon rectangular or other geometrical figures, and that the Greeks, at any rate, achieved thereby a unity and completeness of proportion that is without parallel in the history of art. Mr. Jay Hambidge has outstripped all other investigators in the elucidation of the principles of Greek design, and it is upon his examination of Greek pottery that this paper is based.

It may be thought that such a commonplace article as a clay pot is unworthy of the attention of the artist and scientist, but the Greek vase is altogether unique. Its perfection of shape represents an artistic miracle, and, while its painting and decoration was not always of surpassing excellence, its extraordinary beauty of form makes it one of the greatest art fabrics ever created. The golden period of its production lasted for some three centuries round about 500 B.C., and was thus contemporaneous with the greatest period of artistic fertility the world has ever known. In architecture the creations of Ictinus and Callicrates have never been rivalled; in sculpture the works of Myron and Pheidias represent the climax of that art; in drama, the highest form of literature, Aeschylus and Sophocles stand second (if second) only to Shakespeare; and the names of Plato and Socrates still command the reverential admiration of all philosophers. The names and works of others have disappeared from the scrolls of fame; but we know that artists no less mighty flourished during the same period in the fields of ceramics, dancing, singing, and acting. It is hardly too much to say that in a short three hundred years, in one city whose population scarcely exceeded that of Auckland to-day, there lived a greater aggregation of mighty artists than could be drawn from all other parts of the world in all the rest of time. But in its effect upon the economic and commercial greatness of Athens the potter's art stood supreme. The fabrication of pottery was first developed in Argos and Corinth, and their vases were exported to all the then known civilization. Avenues of trade opened up to all the ports of Egypt, Asia Minor, the Aegean islands, and Italy; and the commercial and naval fleets of Corinth made the might of that little town known from the Nile to Genoa. Gradually, however, the laws of dynamic symmetry were formulated in Athens, and the divine perfection of the resulting pottery drove the vases of Argos and Corinth from the markets of the world. The ensuing jealousies and bitterness in trade circles brought on the Peloponnesian War, and after this struggle the unsettled conditions, particularly of the foreign markets, crippled the trade. Colonized Greeks in the Italian towns began to supply the local demands—always, however, with showy and inferior articles—and the "glory that was Greece" departed for ever. It is difficult now to realize the extent of this manufacture, but it is certain that it was easily the most important source of the wealth of Athens. Here is one illuminating fact: The Pan-Athenaic games, which almost rivalled the Olympic in importance, were held every fourth year. At these games vases formed the prizes, from six to a hundred and forty being presented to each winner, and it is known that over 140,000 were given in this way during the golden two centuries in which Greek intellect blossomed, fruited, and faded.

The dominating factor in Greek life and thought was its intellectual quality: everything was clear-cut, lucid, and defined; even religion had all mystery and spiritual significance stripped from it, and the gods were superhuman only in their mentality and humanity. Greek art moved in a parallel channel and revealed the golden dawn of intellect; in a period when greater freedom of thought existed than has ever been known in any other civilization, it reached a purity of form and perfection of simplicity that showed all non-essentials and redundancy cleared away. Ethical conceptions originated in and were governed by the aesthetic sense. The Greek sense of proportion aimed at the bull's-eye of absolute perfection; their structural compositions achieved unity through the absence of all redundancy and loaded ornament, and through the willing self-surrender of all component parts to the design of the whole. The power of persuasion can be better exercised through the sight than through the reason, and the visual perception of unity, harmony, proportion, and completeness leads to ethical conception of the same qualities. The Greek idea of art was not realism, but art was looked on as an illumination of perfection and as a witness of ethical truths by demonstrating beauty and simplicity. Greek art is the only art which is sufficiently aesthetic to be ethical. As may be expected, however, this simplicity is only a mask for a subtlety to which there is nothing comparable in other schools of art. There is nothing so difficult and so elusive as an artistic simplicity, and it demands absolute perfection in design and workmanship if success is to be achieved. Now, in considering Greek pottery we are dealing with the last word of success in this artistic simplicity, and with the forms of design used by the best artists and craftsmen the world has ever known. Therefore the rediscovery of the mathematical principles underlying the design of the Greek vase is of supreme importance, and these I will now proceed to lay down. It is surely time I reached dynamic symmetry.

As I hinted before, design was based upon and formulated by the aid of rectangular figures. This was known to the Romans, and there is a passage in Vitruvius asserting the fact, but asserting it in a misleading manner. He believed that these rectangles were so chosen that the lines of the vase (as of the building or sculptured figure) bore a certain integral, or at least commensurate, proportion to one another. But the Greeks builded better than this. They realized that the vase (and all solid bodies) was a form which had areal rather than linear dimension as its guiding feature. The rectangles, then, had to be so chosen that the finished design was commensurate in area rather than in line. Now, the area of a square or circle drawn on any line is proportional not to the length of the line but to the square of that length. The proportion of the rectangle—*i.e.*, the ratio between its height and breadth—had therefore to be $\sqrt{2}$, $\sqrt{3}$, $\sqrt{4}$, $\sqrt{5}$, ... rather than 2, 3, 4, 5, ... This is the basis of areal symmetry or proportion.

Fig. 1 shows three of the rectangles chiefly used in Greek design. There is perhaps no ground for the assumption that any one of these shapes is more beautiful than the others, although Plato thought that the root-three rectangle held that pre-eminence. Beauty is, of course, more a matter of functional co-ordination between the utility and the aesthetic value of the shape; but, as we will see, there is sound reason for holding that the rectangle whose ratio of height to breadth is expressed by $\frac{1}{2}(\sqrt{5}-1)$, the rectangle known as the rectangle of the whirling squares, is the natural shape to follow in design.

By considering representative samples of their vase design we will now see how the Greeks used these rectangles. If in any of these rectangles the diagonals are drawn, and also the perpendiculars to each diagonal, from the opposite angles, then the tracing of horizontal and vertical lines through the resulting points of intersection will divide the rectangle into similar but reciprocal rectangles whose areas bear an integral ratio to the area of the whole figure. The dotted lines in fig. 1 show these construction-lines, and, taking the root-three rectangle for instance, it can easily be shown by geometry that the figure ABFE is one-third of the whole rectangle, and that the ratio of its sides is still root-three to 1, the only difference being that the breadth is now the first figure of the proportion instead of the height. Shapes drawn inside these rectangles, and having their salient dimensions determined by any of the dotted construction-lines, will therefore have an inherent unity and coherence in their design,

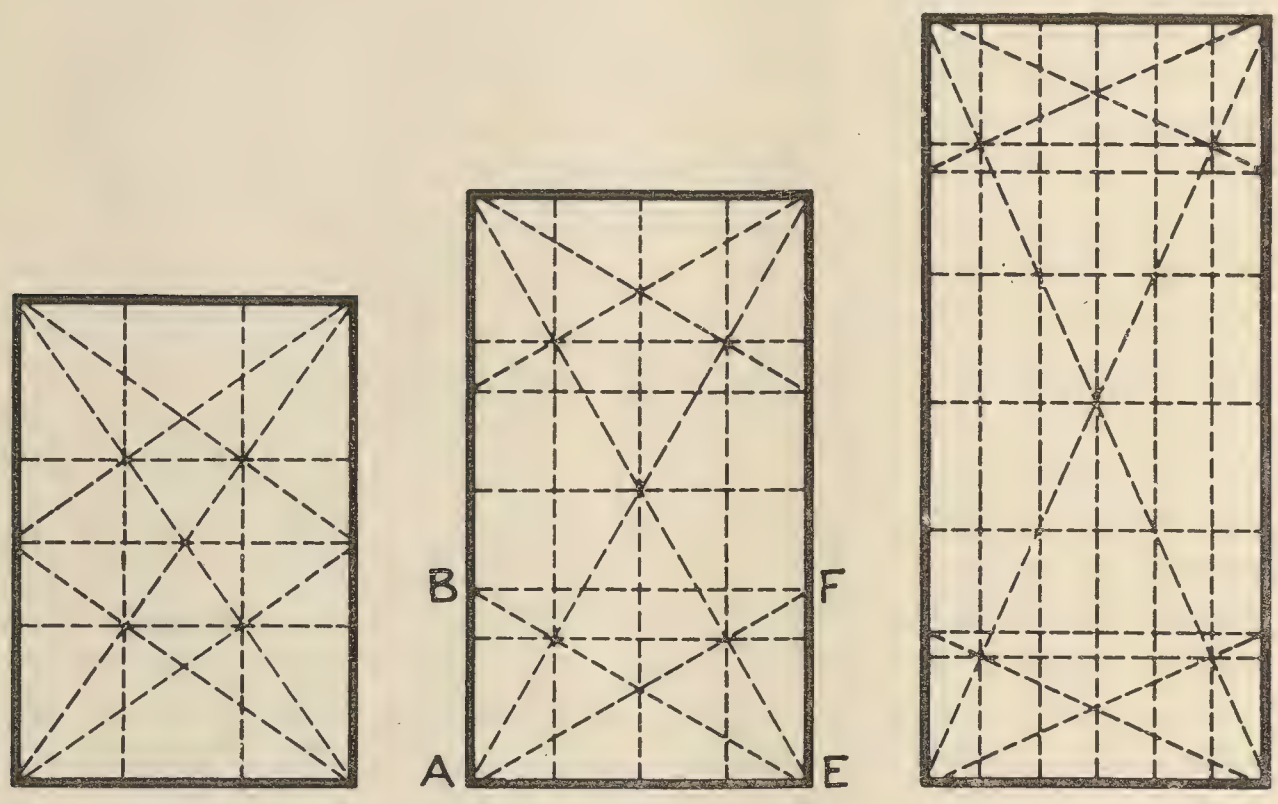
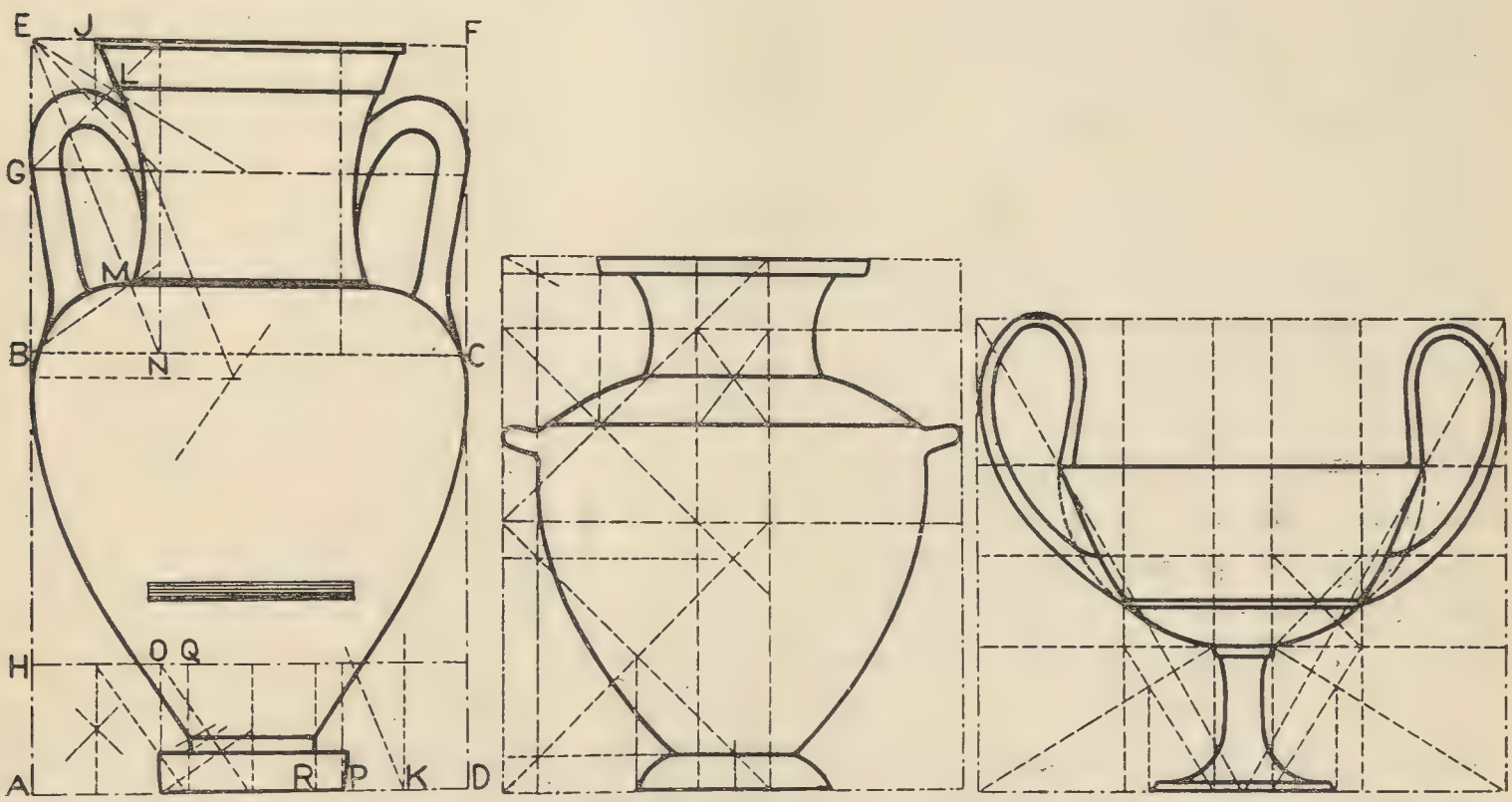


FIG. 1.—Rectangles used in Greek design.

due to the fact that there is an underlying definite and unchanging proportion between the various parts. This satisfies the essential principle of symmetry; and the essential principle of dynamic symmetry, that the proportion should be based on areal rather than on linear dimensions, is also satisfied if the shape is used as the template or pattern of a circular vase. The Greeks, however, were seldom content with quite such simple geometrical figures as these, although the fundamental principles of their design are simply those indicated. Two or more of these basic root rectangles might be combined to form one figure; often squares were added, drawn on either or both sides of the rectangle; again, squares, or rectangles having the same proportion as the main rectangle, might be constructed internally on any of the lines given by the tracing of the diagonals and perpendiculars indicated by the dotted lines in fig. 1. It can be demonstrated simply enough by geometry that such complication still allows the fundamental proportion to be maintained, and the Greeks were careful to maintain this. The position of every point, line, and curve of the finished vase was determined by the intersection of, or drawn tangent to, the lines given by these geometrical figures.

Fig. 2 shows representative specimens of beautiful Greek vases from the collections in American museums, with the analysis of their design made by Mr. Hambidge. The Nolan amphora, or vessel for storing oil (how much more satisfying aesthetically than a kerosene-tin !), may be described as a theme in root-two. The circumscribing figure is composed of a square ABCD, on the side BC of which is drawn a root-two rectangle BEFC. On the lines AD and EF root-two rectangles DG and FH are next drawn. Through the intersections of the diagonals of the square on EG a line is drawn to J, giving the width of the lip. The rectangle JK is then drawn, and its diagonal JK gives the angle pitch of the lip, the thickness JL of the lip, and the position of the widest part of the vase. BM is a perpendicular drawn from B to the diagonal EN, and M determines the foot of the neck. The foot of the amphora is arrived at in a similar manner—OP, for instance, being a root-two rectangle, and



NOLAN AMPHORA. ROOT-TWO THEME. HYDRIA. ROOT-THREE THEME. KANTHAROS. ROOT-FIVE THEME.

FIG. 2.—Amphora, hydria, and kantharos.

QR a square placed in the centre of the shape HD. There is no need to pursue the geometry of the design, but the position of every salient point of the vase may be traced in a like manner. The hydria from the Stoddard Collection at Yale is an example of a root-three design, while the strikingly beautiful kantharos of the Boston Museum is based on root-five rectangles.

This brings us to the most interesting of all the root rectangles, and one which appears to hold within itself the true secret of all design. Intimately concerned with all vegetable and animal growth is the series of numbers known as the Fibonacci series, or the ϕ (phi) progression. The word Fibonacci derives from the family name of Leonardo de Pisa, who, in the year 1228, wrote a mathematical work in which the solution of the following problem appeared for the first time: "How many pairs of rabbits will proceed from one pair, if in every month a new pair is produced, which from the second month on are similarly productive, deaths being supposed not to occur ?" The numbers of pairs at successive months are expressed by the series 1, 2, 3, 5, 8, 13, 21, 34, 55, 89, 144, &c. This series is the nearest integral approximation to a geometric series in which every

term is the sum of the two preceding terms. There is only one such series, and its ratio is given by $r = \frac{1}{2}$ (root 5 — 1) = 1·618...

Now, in the Fibonacci series above each term is the sum of the two preceding terms, and the ratio between each term is nearly equal to 1·618..., and does in fact approach infinitely near to 1·618... as the series proceeds to infinity. This ratio 1·618... is known as "phi." In any animal or vegetable matter which grows by the generation of new individuals or cells from existing ones either the number in successive generations is, or tends to be, expressed by the terms of the Fibonacci series, or the volume of each cell to the preceding one is in the ratio of 1·618... to 1. As examples of the first alternative we have the pine-cone, whose scales run in curved series of 5, 8, 13; the daisy, in whose disc the petals run in curved series of 21 and 34; or the sunflower, whose florets run in 34 and 55 rows, in 55 and 89 rows, or (in very large flowers) in 89 and 144 rows. A good example of the second case is the nautilus shell, which consists of cells whose volume is in the phi ratio, and these are twisted round upon the smallest till they lie in a logarithmic spiral, the equiangular *radii vectores* of which bear also the phi ratio to one another. The most pressing problem assailing a plant in its phyllotaxis, or leaf-distribution, is to find that angle of distribution of its leaves about the central stem which will give the minimum interference vertically and thus allow the maximum amount of light or rain to reach each leaf. Plants have sufficient knowledge of the higher mathematics to solve this problem, and accordingly the leaves tend to be thrown out at angles of 137° 30′ 28″, the important point for our purpose being that the four right angles of the circular plan a e thus divided into ϕ^2 or $(\phi+1)$ equal parts. For phi has the convenient and unusual property that while phi is equal to 1·618..., phi squared is equal to 2·618..., and the reciprocal of phi is equal to 0·618... Dimly revealed through these natural facts lies the assurance that the phi progression and the phi ratio (1·618...) is the underlying law of vital growth, and therefore the underlying law both of the artist's expression of the beautiful and of our appreciation of it. Experimenters in psychology have tested the appreciation of beauty in two simple but fundamental experiments. In the first a class was asked to divide any straight line in that proportion which appeared to them most satisfying, and in the second they were asked to draw that rectangular figure which seemed most pleasing. The average of their answers to the first showed the line divided in that way which Euclid, with his usual matter-of-factness, described as cutting it in extreme and mean ratio, but which more imaginative geometers have always known as cutting it in "golden," or better still, "divine" section. For from the earliest time unusual virtues have been ascribed to this method of section, and you will have guessed already that these are due to the fact that the line is so divided that the longer part is phi (1·618...) times the shorter. The average of the answers to the second question was a rectangle whose longer side was again phi times the shorter. Again, among all curves known to the geometer the logarithmic spiral is the most fascinating in its properties. The involute, the evolute, the pedal, and the caustics by reflection and refraction of a logarithmic spiral are equal logarithmic spirals, which facts of "perpetual renascence" so delighted Bernouilli that he directed a logarithmic spiral should be engraved on his tomb, with the emphatic inscription "Eadem mutata resurgo." The great masses of cosmic matter in the Milky Way and other nebulae are, of course, spirals, if indeed the whole universe is not a logarithmic spiral of

nebulae whose component masses again assume the logarithmic spiral form. And the logarithmic spiral differs from all other spirals in that the ratio between its successive *radii vectores* is our mystic number phi.

The rectangle whose longer side is phi times the shorter was naturally a favourite one with the designer of Greek pottery. This rectangle has one very curious property. In fig. 3 is shown the phi rectangle ABCD; from A a perpendicular AOE is drawn to the diagonal BD, and a vertical line EF is drawn through E. The phi rectangle is now divided into a square CF and a phi rectangle FD. If this construction is repeated indefinitely for this new phi rectangle and the consequent ones, we obtain a series of phi rectangles and a series of squares, the squares gradually folding themselves about the point O in such a manner that their centres lie on a logarithmic spiral whose pole is at O. This is shown in fig. 3, and it is from this property that the phi rectangle derives its usual name —*the rectangle of the whirling squares*. Further, the side of each square bears the phi ratio to the side of the square preceding it. A good example of the happy results obtained when vases were designed by the aid of this rectangle is shown in fig. 4, a black-figured eye kylix from the

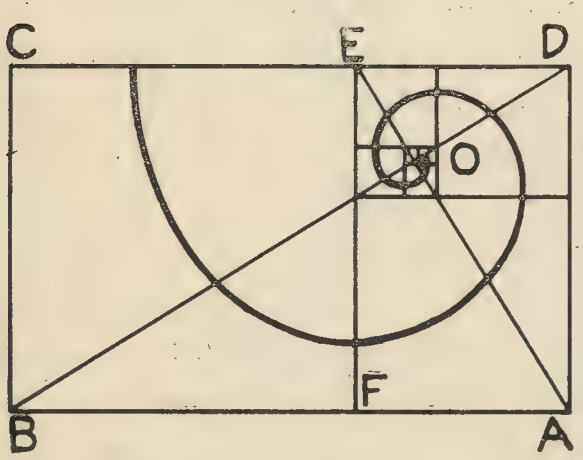


FIG. 3.—Phi rectangle.

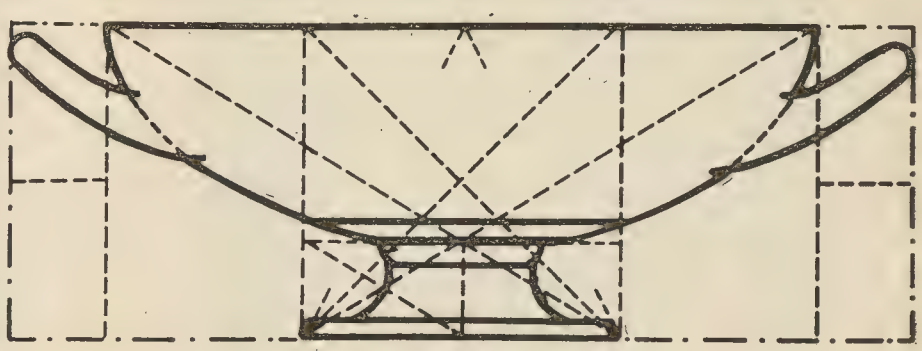


FIG. 4.—Kylix—a phi theme.

Museum of Fine Arts at Boston. But its use was not confined to the ceramic arts only. The research of Mr. Hambidge is still under way in the fields of architecture, sculpture, and painting, but the results already obtained show quite clearly that the symmetry and rhythm of the Parthenon, of the Pheidian statues, and of the perfect human figure as revealed in the Botticelli "Venus" and other ancient masterpieces are directly traceable to the skilful use of the phi rectangle or the phi progression. The design of the Parthenon has been analysed under the guidance of the principles of dynamic symmetry, and the proportions as determined to the minutest detail show conclusively that the theme of the building throughout falls into a rectangular figure composed of two whirling-square rectangles.

As regards statuary it has always been known that Pheidias, the greatest of all sculptors, worked religiously to very strict rules and proportioned all parts of his human figures to a certain ratio whose value had unfortunately been lost. This was always referred to as "the ratio of Pheidias," and it has been proved by Mr. Harold Speed* that its value was 1·618....., and hence this number has been given the symbol ϕ (phi), the initial letter of Pheidias. In painting also this ratio must govern the drawing and placing of the human figure, and the use of the phi

* HAROLD SPEED, *The Practice and Science of Drawing*, p. 289 (Seeley, Service, and Co., London, 1913).

progression is illustrated in the Botticelli "Venus" of fig. 5, and the "Laughing Cavalier" of fig. 6. The Grecian painters invariably used squared surfaces for their drawings, lines being drawn across the picture at varying distances apart, these distances being determined by the values of successive terms in the phi progression. This progression is that geometric series, of which the Fibonacci series is the integral approximation, in which each term is the sum of the two preceding terms and the common ratio is phi. In algebraic and arithmetic form it is expressed by

1	ϕ	ϕ^2	ϕ^3	ϕ^4	ϕ^5	ϕ^6	ϕ^7
1	1·618...	2·618...	4·236...	6·854...	11·090...	17·944...	29·033...

The cross-lines then were drawn at distances apart corresponding to the arithmetical values of this series. Many great works of art have been produced without the knowledge of this ratio, but in general the salient points of their design—that is, those parts of the picture whose placing appears to govern that impression of symmetry, balance, and rhythm, which is the distinguishing feature of all great art—these salient points fall very closely on the points obtained by a judicious setting-out of the phi series.

Indeed, this is instinctively felt to be correct. The processes of growth are indissolubly linked with the phi ratio, the phi progression, and the phi spiral. It is only natural, then, that these proportions have an intimate connection with the source of our pleasure in contemplating a beautiful flower, plant, or shell, or of an impressive work of art. So closely associated are they with the fundamental laws of vital, if not of cosmic, growth that it is impossible to resist the conclusion that the phi ratio represents a mathematical expression for the ideal proportions of structural form towards which nature is continually tending, and is therefore a guide to the artistic expression of the beautiful. It does not, of course, provide a recipe by which any modern mathematician can produce a rival to the masterpieces of Hellenic sculpture or to the paintings of a Botticelli, but, if the knowledge of the use of this ratio had not been lost, artists of to-day would undoubtedly have been creating masterpieces of architecture, statuary, and painting surpassing those of the Greek classic age.

It may be objected that all this tends to make art mechanical; but the contrary is true. In so far as the drawing of squared lines on the canvas simplifies and shortens the work of the artist, all is pure gain; the more mechanical aids are given to the painter, the more his energy can be directed towards the true artistic problems of his work. For art is not realism, and is more than photography. Art must be based on the underlying structure of nature, and not upon the superficial appearance. Nature is tending always towards an ideal, and only the realization of this ideal and an understanding of the significance of structural form can enable the artist to become creative and anticipate nature. Not otherwise can man be creative, be aesthetically free. And only in the phi progression is there promise of a natural law which can be made applicable to the needs of artistic symmetry and formalized design. Design without any underlying and basic symmetry can produce no satisfying harmony of functional parts, and is quite devoid of that sense of inevitableness which is the hall-mark of creative instinct in the novel and the drama, in the sonata and the symphony, or in the painting and the statue and the vase. Even the Hopi Indians designed their vases by tracing them inside a circumscribing figure of elliptical shape drawn to the proportions of an egg—and the ratio of height to breadth in the average or ideal egg is almost exactly the phi ratio! Lafcadio Hearn, writing about 1900, and

ignorant of dynamic symmetry, says, "I don't believe the Greeks knew anything about anatomy. The astounding thing is that the great Italians who studied osteology—who drew the skeleton before covering it with painted flesh—never approached the commonest Greek outline. What is the awful—really *awful* secret of their knowledge of grace? We know the geometrical rules for the face. But those for the limbs! and the torso—and the divine symmetry of the rest—we cannot find. We know they drew by rule, squaring off the surface with cross-lines first. But what was the rule and how did they find it?" In the Romanes Lecture delivered at Oxford in 1909 by Mr. Arthur Balfour, that suave and eloquent exponent of philosophic doubt said, "It is absolutely hopeless to find a scale, in matters aesthetic, which shall represent, even in the roughest approximation, the experiences of mankind." But a scale and

FIG. 5.—The Botticelli "Venus."

FIG. 6.—"Laughing Cavalier." (Franz Hals.)

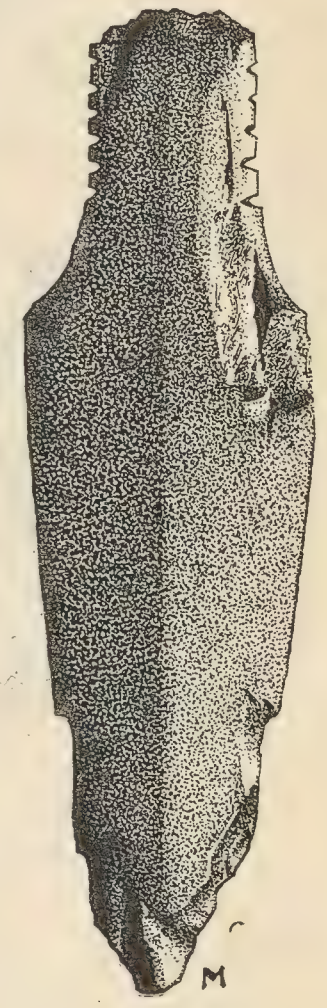
a rule have been found—a scale which agrees to the minutest detail with the proportions of those masterpieces of pottery, architecture, and statuary which represent in their respective domains of aesthetics the absolutely highest experiences of mankind. Dynamic symmetry does provide a rule and a scale—a scale which can already be claimed to be much more than a rough approximation to those hidden principles of symmetry, balance, harmony, and rhythm which are inherent in the noblest masterpieces of creative art. Whether it offers a tangible explanation of the psychological impulses that underlie our appreciation of the beautiful is more difficult to decide.

That reminds me—I promised to explain in a few well-chosen words the secret of that mysterious and hitherto inscrutable fascination which beauty exercises over the human mind. I am sorry that lack of time prevents me redeeming my promise here and now. *Mutatis mutandis*, this was the close of a very eloquent address on "Music" by the celebrated Haweis, and will serve very well for a close on this occasion.

NOTE ON A STONE OBJECT RESEMBLING A DAGGER-BLADE.

By LINDSAY ROGERS, University of Otago.

ONE mile and a half due north of the rugged point on which Cape Saunders Lighthouse stands is a small bay called Little Papanui. The only way to reach it is to walk over from Portobello till one comes in sight of the lighthouse, and then to strike due north. A walk of a mile or so over turf brings one to the beach. Seen from a distance it does not seem a very promising place for an encampment, but a closer examination leaves a different impression. At the northern end of the bay is a rough rocky shore, with bush almost to the water's edge. The southern end of the bay, backed by paddocks and flanked to the south by cliffs, is composed of one long sandhill. Two small creeks enter the bay, one about the middle, the other beside the sandhill at the extreme southern end.



Stone object resembling a dagger-blade. One-fourth natural size.

This southern creek meets the sea at the angle formed by the cliffs and the sandhill, and it was here, apparently, that the domestic life of the local Maoris centred. On the hill to the south of the creek and on the sandhill to the north are strewn stones from old ovens and all the other debris of a long-established settlement. Flakes of crude opal abound, knives of quartzite and implements of schist are fairly plentiful. Greenstone, both worked and unworked, is frequently met with, and numbers of bone implements have been secured by different collectors.

Possibly the inhabitants of the settlement, which seems to have been a large one, were annihilated by some hostile *taua*. Possibly some epidemic swept them off and the site became *tapu*. Whatever the explanation, collectors have found the place an extraordinarily rich one.

The blade which is the subject of this note was found embedded in the bank of the creek, in a layer of burnt charcoal, sand, and fish-bones. The material of which it is made is jasperlite. Professor D. B. Waters, of the Otago School of Mines, informs me that this occurs *in situ* in the country about the upper reaches of the Waitaki. We have no evidence as to whether the piece in question was secured by its Maori maker *in situ* or in the river gravels. That jasperlite was prized by the natives—probably on account of its rich red colour—is indicated by its use for articles of a special kind, two of which are in the Otago University Museum collection. One is a broad unfinished breast-pendant of unusual type, while the other is the broken fish-hook shank figured by Hamilton in *Dominion Museum Bulletin No. 2* (fig. 10, upper row, right). The blade is 14 cm. long, but was originally somewhat longer. Its maximum breadth is 4·3 cm. In cross-section the blade is

a very flattened diamond which is not bilaterally symmetrical, the side shown in the illustration having a more pronounced median ridge than the reverse side. One edge of the blade is sharp, while the other is blunt. On one side of the tang are six notches, and on the other are five. The finish of the whole object is good, though the marks left by the last polishing are clearly discernible.

As to its use we are left purely to conjecture. The stone is not so hard as greenstone and is somewhat flaky, and the object is therefore probably unsuitable for use as an actual weapon. It may be suggested that it was designed as a pendant. The shape suggests that it is a copy of some metal prototype. The notches on the tang strongly suggest that in the prototype slats of wood or bone were attached to round out the handle. One is tempted to suggest as the model some early form of Malayan *kris*.

The suggestion of an East Indian model might seem far-fetched were it not that many features in Maori culture show undoubted affinities with that region. The evidence of the object under discussion seems to receive support from the slate object found at Orepuki,* in the same culture area, which has been described as a copy in stone of a sword or dagger hilt.†

The object described in this note has been presented by the finder to the Otago University Museum.

I have gratefully to acknowledge the advice and assistance rendered by Mr. H. D. Skinner, Lecturer on Ethnology, Otago University, in the preparation of these notes.

FUSION, SOLUTION, AND IONIZATION.

By W. F. SHORT.

IT is well known that solution and precipitation from solution resemble fusion and solidification in many respects. Thus if a mixture of salt with its saturated solution is subjected to pressure, more salt is dissolved if the solution occupies a volume less than that previously occupied by the constituents. If the volume of the solution is greater than that of the constituents, increase of pressure causes a separation of salt from the solution. Again, both melts and saturated solutions may be supercooled. Solution also resembles fusion in requiring, in general, a supply of heat to effect a change of state, although in some cases the "heat of solution" is positive. From these general resemblances, and also from the fact that fusion and solution are "surface" phenomena, solution is regarded as an exchange process, a saturated solution in contact with its salt taking up and depositing equal quantities of salt. The influence of temperature is

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* Corrupt form of Maori name, Aropaki.—EDITOR.

† MACMILLAN BROWN, *Maori and Polynesian*, p. 198: "It looks like the handle of a stone dagger." A. HAMILTON, *Trans. N.Z. Inst.*, vol. 35, p. 114, 1903: "Carefully worked into the shape of the handle and guard of a dagger or small sword. . . . It is too small to be used as a dagger or weapon of offence, though the shape at once suggests such a purpose."

especially interesting and adds a further weight to the view that solutions of solid substances should be treated as solids in a fused condition at ordinary temperatures. Turning again to the question of electrolytic conductivity, we find this property is associated with the fluid state of matter, the conductivity of most solids being metallic and not electrolytic. In the case of ionic dissociation the temperature coefficient is usually positive, and it is usual to explain this effect by assuming increased ionic mobility with rise of temperature. Thus it appears that fusion, solution, and ionization are intimately related phenomena, and a theory of solution and ionization to be successful must take this fact into consideration and at the same time provide a satisfactory explanation of the influence of temperature on these changes. In the present paper an attempt is made to provide such a theory by an application of the radiation hypothesis (W. C. McC. Lewis, *Trans. Chem. Soc.*, vol. 105, pp. 2330 *et seq.*, 1914), to the phenomena under consideration.

I. FUSION.

The explanation of melting is mainly due to Lindemann, Stein, and Nernst, whose views may be briefly summarized as follows: At the absolute zero of temperature the specific heat of a substance is zero, and all molecular motion has therefore ceased. In a solid the energy of the molecules is almost entirely vibrational, half kinetic (due to vibrations about a position of equilibrium) and half potential (due to the distance of the atom from this position). As the temperature rises, the amplitude of the vibration increases until, at the melting-point, the whole of the molecules (or atoms) possess amplitudes almost equal to their distances apart. The application of more energy, the latent heat, causes the solid to melt by increasing the amplitude of vibration to a value greater than the distance of the molecules (or atoms) apart.

It will be observed that the increase in energy is supplied in the form of radiation, due to an increase in temperature. Stein has obtained evidence in support of this theory by observations on the behaviour of solid substances towards infra-red rays.

II. SOLUTION OF SOLIDS IN LIQUIDS.

From almost the earliest times to the present the solubility of substances has formed the subject of scientific inquiry. Such a vast amount of work has been recorded, and so many conflicting opinions have been expressed, that it is impossible to attempt a survey of them. (A systematic study of the literature bearing on the question up to 1912 is to be found in a report by Eyre—*British Association Reports*, 1910, p. 425, and 1912, p. 795). At the present time no entirely satisfactory theory is known, although only two rival theories now share the field. According to the hydrate theory, as developed by Mendeleef, Armstrong, Pickering, and Jones, solution is a chemical process due to the production of a series of solvates. Nernst, Ostwald, and Arrhenius, on the other hand, maintain that the process of solution is perfectly similar to that of vaporization, specific attraction between solute and solvent being considered to be non-existent.

The theory about to be advanced does not preclude the formation of solvates; indeed, their formation is considered to be necessary in many cases.

Returning now to the case of fusion, we find that a solid is infinitely soluble in its own melt—that is, a fused salt is the ideal solvent for that salt. The reason for this is, of course, that the amount of the solvent is not constant, but continuously increasing. At the same time, the most soluble substances we know take much longer to dissolve in a solvent than they do to produce a solution of equal concentration in their own melt. If we assume that the latent heat necessary to bring about such a solution is supplied to the solid in the form of radiation absorbed by the liquid melt an explanation of the above phenomenon would be supplied. It is reasonable to suppose that a melt will have approximately the same absorption spectrum as the solid at temperatures near the melting-point, and hence will behave *as a reservoir of radiant energy of the vibration frequency absorbable by the solid.* On this view the production of an ideal saturated solution—that is, one in which neither association nor dissociation of the solute nor solvation occur—would be described as follows: Radiant energy is communicated to the solute by the solvent, and thereby the solute molecules become possessed of the necessary kinetic energy to allow them to assume the liquid condition—that is, to dissolve. The solution continues until an equilibrium is reached between the "dissolving" force and the forces tending to drive the solute from the solution (osmotic pressure, attraction of the solid solute for the solute molecules in solution, &c.). An explanation of the different rates of solution of a solute in different solvents follows from the fact that the solvents have different absorption spectra, and the effect of temperature is also explained. In the great majority of cases increase in temperature produces increase in solubility, as the theory demands; those substances which show the opposite behaviour are "abnormal," in that they are solvated.

III. IONIZATION.

The opponents of the dissociation hypothesis emphasize the fact that it provides no *motive* for electrolytic dissociation. An extension of the theory of solubility outlined above would seem to overcome this difficulty, for we have reason to believe that if sufficient energy is communicated to any substance it will decompose, and ionization is a variety of decomposition. In this connection it is significant that fused salts have frequently a high electrolytic conductivity. The melt of an electrolyte would naturally be the ideal dissociating solvent for that substance, owing to the similarity or identity of the absorption spectra of the solid and its melt. It does not follow that a substance should always be highly dissociated in its melt, since some molecules are so stable that communication to them of this maximum of absorbable radiation may produce but little ionization. It does follow, however, that an electrolyte should usually be more highly dissociated in its own melt than in other solvents.

A calculation has shown that the radiation necessary to produce ionization at the ordinary temperature will be of shorter wave-length than that required to produce solution, hence it does not follow that the temperature coefficient of ionization must be positive, since we are here concerned with the ultra-violet region of the spectrum, not the infra-red. The temperature coefficient will be determined by the effect of temperature on the "heat of dissociation" and on the ionic friction.

Support is given to this theory by the relationship known to exist in many cases between the dielectric constant of a solvent and its ionizing-power.

DEPARTMENTAL REPORT.

Notes on the Geology of New Zealand.

(To accompany Geological Sketch-maps.)

By P. G. MORGAN, M.A., F.G.S., Director of the Geological Survey of New Zealand.

THE following notes on the geology of New Zealand and the maps published herewith were prepared at the request of Dr. W. N. Benson, president of Section C (Geology) at the meeting of the Australasian Association for the Advancement of Science held last January in Melbourne, and were originally intended for publication in the *Report* of the Association. Personally, I would have liked to wait a few years longer before expressing opinions which in some cases are based on weak foundations. On the other hand, the publication of maps illustrating, however imperfectly, our existing knowledge of the geology of this country is clearly called for, and explanatory remarks of some kind are necessary.

The compilation of the maps has been more difficult than might be supposed. This has arisen from various causes. Firstly, the geological structure of New Zealand is extraordinarily complicated, and consequently the geological map becomes a thing of shreds and patches. Secondly, the geology of some parts is not at all well known. Thirdly, New Zealand geologists have differed greatly on vital points, and accounts of one and the same area are often fundamentally irreconcilable. Fourthly, the fact that the geology of some areas has been worked out in detail makes it difficult to represent the geology of less known areas on the same map in the same way; and, moreover, portions of the boundaries shown on sketch-maps of former workers have to be arbitrarily altered so as to make them fit in with the more detailed surveys of recent years. Fortunately, perhaps, the small scale of the maps now presented makes it possible to hide a multitude of errors.

The principal geological maps of New Zealand hitherto published are the following:—

1864. F. von Hochstetter and A. Petermann: "Geological and Topographical Atlas of New Zealand." (Deals only with Auckland and Nelson.)

1869. James Hector: "Sketch-map of the Geology of New Zealand." $25\frac{1}{2}$ in. by 18 in.

1873. James Hector: "Geological Sketch-map of New Zealand." 33 in. by $21\frac{1}{2}$ in.

1884. James Hector: "Sketch-map of the Geology of New Zealand." Published in *Rep. of Geol. Explor. during 1883–84*, No. 16, opposite p. 1. $18\frac{3}{4}$ in. by $13\frac{1}{4}$ in. (See also *Outline of N.Z. Geology*, opposite p. 88, 1886.)

1910. James Park: "Sketch-map of the Geology of New Zealand." Published in *Geology of New Zealand*. $18\frac{1}{2}$ in. by $12\frac{1}{4}$ in.

1912. P. Marshall: "Map of New Zealand, geologically coloured." Published in *Geology of New Zealand*. $19\frac{1}{2}$ in. by $13\frac{1}{4}$ in.

Small geological maps of the North and South Islands of New Zealand, compiled in the Geological Survey Office, were published in the *New Zealand Official Year-book* for 1914, and again in the 1916 volume.

The geological divisions shown in the various maps mentioned above, except Dr. Marshall's, are named according to the supposed European equivalents only. In the present paper and the accompanying maps both European and New Zealand formational names are used. Several awkward decisions could have been avoided by using only New Zealand names for the main divisions, but it is thought that the use of the European time-scale, in spite of the more or less valid objections that may be urged, will render the map more intelligible to geologists of other countries.* The necessary mental reservation — namely, that the New Zealand divisions correspond only roughly to the European time-scale—is one easily made and borne in mind. The geological boundaries shown on the maps have been copied from numerous old maps, and as a rule have not been modified except where it was necessary to adjust them to more modern work. Although it was known that in many cases the original maps were decidedly inaccurate, it was felt that to sketch new boundaries would simply be to introduce new errors.

In the map of the South Island the Pelorus series (of probable Palaeozoic age) has inadvertently been included with the Trias-Jura system. This, according to Marshall, is its true position. In south-west Otago (Fiordland) too great an area has been assigned to the Manapouri series, which is meant to include only rocks of probable pre-Ordovician age.

OUTLINE OF GEOLOGY.

Pre-Palaeozoic and Palaeozoic Rocks.

The oldest rocks in New Zealand are supposed to occur in western Otago (Fiordland), where, over a considerable area, is exposed a complex of dioritic gneisses and schists (Manapouri† series of Hutton, 1875 and 1885) intruded by granite and other igneous rocks. There is no direct evidence of the age of the Manapouri schists and gneisses. It is here assumed that they are older than the greywackes and argillites near Preservation Inlet, which contain graptolites of Lower Ordovician (Lancefieldian) age. They may therefore be Cambrian as suggested by Park, or pre-Cambrian as Hutton originally thought. In 1899, however, the latter included the gneisses in his Hokanui system.

In a recent private communication Professor Park states his view of Fiordland geology as follows: "The diorite intrusive complex occupies the whole of the mountain country to the west of Lakes Hauroto, Monowai, Manapouri, and Te Anau as far as the heads of the Sounds. Hector mapped the whole of this area as occupied by the Archaean gneissic series, and I followed suit, not having previously visited the main divide west of the lakes. The Archaean gneisses, schists, and limestones occupy only a narrow strip from Dusky Sound northward, petering out north of Caswell Sound." Professor Park now considers the dioritic intrusives to be of Late Permian or perhaps Early Triassic age.

In the north-western part of Nelson, schists and gneisses associated with rocks containing Lower Ordovician (Castlemainian) graptolites have been placed in the same series (Aorere) as the fossiliferous strata, but are almost certainly older. Unconformable relations are suspected to exist, but clear evidence of this is lacking. At the same time it should be mentioned that apparently unconformable contacts between Ordovician

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* See O. WILCKENS, Die Geologie von Neuseeland, *Geol. Rundschau*, Bd. viii, Heft 3–4, 1917. Abstract in *N.Z. Journ. Sci. & Tech.*, vol. 4, pp. 142–43, 1921.

† Originally spelt "Manipori" by Hutton (1875).

rocks and underlying schists or gneisses have been observed by Ongley in the Collingwood district and by myself in the Westport district.

In Central Otago a large area is covered by the mica chlorite, and quartz schists, which Hutton regarded as of pre-Cambrian age and placed in his Wanaka series. Hector thought that the Otago schists were chiefly of "Silurian" age (in the Murchisonian sense), but might include younger formations. Park places these rocks in his Upper Maniototo series, of supposed Cambrian age. Marshall thinks that there is no good reason for supposing them to be older than Triassic. The most pertinent known facts are that the highly metamorphic schists pass upward into less metamorphic rocks, and that these again seem to pass into greywackes and argillites similar to fossiliferous Triassic rocks south-west and north-east of the schist area. No fossils of any kind have yet been found in the schistose rocks, or even in the only slightly altered greywackes and argillites immediately associated with them. The most reasonable view seems to be that the schists are of Palaeozoic age, and that one or more unconformities, as yet not detected, occur in the vast assemblage of strata placed in the Trias-Jura system by Marshall.

It is not improbable that, as various writers have believed, the gneisses and schists of Westland, which form part of Bell and Fraser's Arahura series, are of approximately the same age as the Otago schists. These Westland rocks, like those of Otago, are non-fossiliferous, and to the east pass upward, without detected unconformity, into rocks containing Triassic fossils, as lately determined by Speight. The schists of Marlborough (Pelorus Sound to Wairau River) may for the present be correlated with the upper part of the Otago schists.

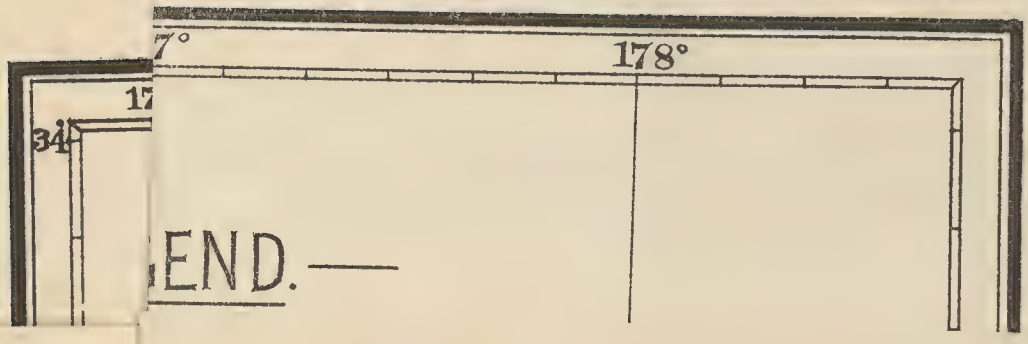
As already mentioned, fossiliferous Lower Ordovician (Aorere) rocks occur in north-west Nelson (Collingwood district) and in south-west Otago (Preservation Inlet). The marbles of Nelson are generally placed in the Aorere series. Throughout western Nelson and in north Westland a thick series of almost non-fossiliferous greywackes and argillites, here assigned to the Aorere series, is widely developed. These rocks contain auriferous lodes, which are the source of much alluvial gold. Silurian rocks occur at the Baton River and near Reefton. Those of the latter locality were regarded by Hector and McKay as of Devonian age.

The Te Anau series of the old Geological Survey in its typical locality (between Lakes Te Anau and Wakatipu), from the descriptions given, seems to consist of conglomerates, tuffs, greywackes, and argillites, together with great masses of contemporaneous igneous rocks. Hector ascribed it to the Devonian, but since, so far as known, it is entirely unfossiliferous, the correlation is doubtful. Of somewhat similar character, and probably of the same age, are the rocks of the Collingwood district placed in the Haupiri series by Bell, Webb, and Clarke, and the rocks on the western side of the Pelorus Valley (Pelorus series, E. de C. Clarke in MS.).

The rocks near Nelson placed by Hochstetter in his Maitai series (thought to be of Triassic age) have provoked much controversy. The old Geological Survey, led by Hector and McKay, considered these rocks, on the strength of their fossils, to be of Carboniferous age. In 1904 Park contended that they were of Jurassic age, but at a later period was reconverted by field evidence to the old view. In 1912 Bell, Marshall, and Clarke, having failed to find any fossils of Palaeozoic types, classed the Maitai rocks as of Trias-Jura age. In recent years, however, Trechmann has demonstrated that the Maitai rocks of Nelson are of the same age as the coal-bearing rocks of New South Wales. They are therefore of Permo-Carboniferous or Permian age.

ERRATA.

THESE maps should be marked Vol. 5, Plates I and II. The accompanying paper was intended for publication in Vol. 4, No. 6, but through an unforeseen circumstance had to be held over.


7°
178°
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34
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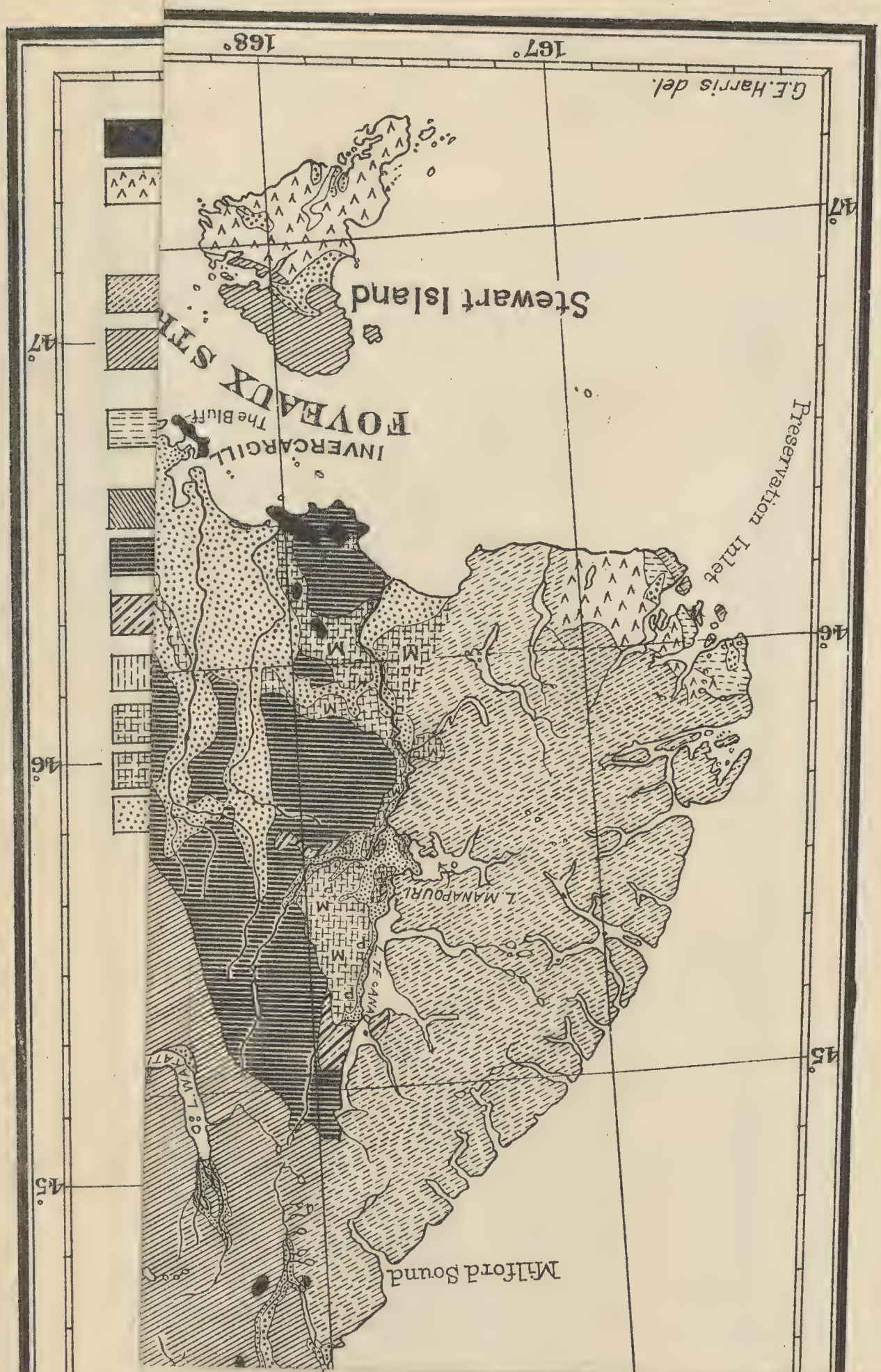
168°
167°
G.E.Harris del.
47°
Stewart Island
INVERCARGILL
The Bluff
FOVEAUX STR
46°
Preservation Inlet
L. MANAPOURI
TE ANAU
45°
Milford Sound

GEOLOGICAL SKETCH MAP OF THE NORTH ISLAND OF NEW ZEALAND

TO ACCOMPANY PAPER ENTITLED "NOTES ON THE GEOLOGY OF NEW ZEALAND" BY P. G. MORGAN.

Scale

ENGLISH MILES 10 5 0 10 20 30 40 50 60 70 80 90

KILOMETRES 10 5 0 50 100

1921

N.Z. GEOLOGICAL SURVEY

— LEGEND. —

SEDIMENTARY ROCKS.

RECENT AND PLEISTOCENE		
PLIOCENE	Wanganui Series	P
MIOCENE / OLIGOCENE	Oamaru Series	M
EOCENE	Waimangaroa or Mawheranui Series	
CRETACEOUS	Waipara Series / Clarence River Series / Port Waikato Plant beds	
TRIAS-JURA	Hokanui System &c	

IGNEOUS ROCKS.

Acidic

Intermediate and Basic

North Cape, Whangaroa, Bay of Islands, Hokianga Har., Whangarei Har., Great Barrier Id., C. Colville, Cuvier Id., Kaipara Har., Hauraki Gulf, Waitemata Har., Coromandel, AUCKLAND, Manukau Har., Thames, Waikato R., Mayor Id., Waihi, Tauranga Har., White Id., C. Runaway, East Cape, Bay of Plenty, Raglan Har., Aotea Har., Kawhia Har., ROTORUA, Gisborne, Poverty Bay, Mokau R., L. TAUPO, NEW PLYMOUTH, Ngauruhoe, Ruapehu, C. Egmont, Mt. Egmont, Hawke Bay, NAPIER, Patea R., Waitotara R., Wanganui R., Rangitikei R., Manawatu R., NELSON, BLENHEIM, WELLINGTON, SOUTH ISLAND, TASMAN SEA, COOK STRAIT, C. Palliser, SOUTH PACIFIC OCEAN

34° 35° 36° 37° 38° 39° 40° 41° South Latitude

172° 173° 174° 175° 176° 177° 178° East Longitude

G.E. Harris del.

GEOLOGICAL SKETCH MAP OF THE SOUTH ISLAND OF NEW ZEALAND

TO ACCOMPANY PAPER ENTITLED "NOTES ON THE GEOLOGY OF NEW ZEALAND", BY P.G.MORGAN.

Scale

ENGLISH MILES
10 5 0 10 20 30 40 50 60 70 80 90

KILOMETRES
10 5 0 50 100

1921

168° 169° 170° 171° 172° 173° 174°

41° 42° 43° 44° 45° 46° 47°

Cape Farewell
Aorere R.
Golden Bay
Collingwood
D'Urville Id.
JT
Tasman Bay
Pelorus Sound
NELSON
COOK STRAIT
WELLINGTON
BLENHEIM
Wairau R.
Awatere R.
Karamea R.
Karamea Bight
Kawatiri or Buller River
Waimangaroa
Westport
C. Foulwind
Charleston
Brighton
Mawheranui or Grey R.
Greymouth
HOKITIKA
Ross
Kaikoura Pen.
Amuri Bluff
Waiau-uha R.
Hurunui R.
Clarence R.
Ashley R.
Pegasus Bay
Waimakariri R.
CHRISTCHURCH
Banks Peninsula
Rakaia R.
Ashburton R.
Canterbury Bight
Rangitata R.
Timaru
Waitaki R.
Oamaru
Hampden
Shag Pt.
Otago Peninsula
DUNEDIN
Green Island
Taieri River
Kaitangata
Clutha R.
Paringa R.
Haast R.
Milford Sound
L. MANAPOURI
L. MANAPOURI
L. HAWEA
L. WANAKA
L. WAKATIPU
Preservation Inlet
INVERCARGILL
The Bluff
FOVEAUX STRAIT
Stewart Island
TASMAN SEA
SOUTH PACIFIC OCEAN
South Latitude
East Longitude

— LEGEND. —

SEDIMENTARY ROCKS.

RECENT AND PLEISTOCENE		
PLIOCENE	Wanganui Series	P
MIOCENE / OLIGOCENE	Oamaru Series	M
EOCENE	Waimangaroa or Mawheranui Series	
CRETACEOUS	Waipara Series; Clarence River Series; Port Waikato Plant-beds	
TRIAS-JURA	Hokanui System &c	
PERMIAN OR PERMO-CARBONIFEROUS	Maitai Series	
SILURIAN	Baton R. or Wangapeka Series	
ORDOVICIAN WITH SOME PROBABLE PRE-ORDOVICIAN	Aorere Series &c.	
UNDIFFERENTIATED AND DOUBTFUL PALÆOZOIC	Maniototo Series &c.	
PRE-ORDOVICIAN (?)	Manapouri Series	

IGNEOUS ROCKS.

Acidic	
Intermediate and Basic	

G.E. Harris del.

Pl. IV.

...n Wales. They are therefore of Permo-Carboniferous or Permian age.

Hector and McKay considered that extensive areas in other parts of New Zealand were covered by Carboniferous strata, but it is now certain that, although Maitai rocks may yet be found in various districts, by far the greater part of the areas in question must be mapped as Mesozoic.

General Remarks on Palaeozoic Rocks.

The known areas of Palaeozoic rocks containing recognizable fossils are only five in number. They are the Collingwood district and Preservation Inlet, with Lower Ordovician fossils; Baton River and Reefton, with Silurian fossils; and the Dun Mountain district, near Nelson, with Permo-Carboniferous or Permian fossils. Everywhere else the exact age of the rocks mapped as Palaeozoic is more or less doubtful, and it is evident that very careful and highly detailed stratigraphical work, combined with such other lines of study as may be available, is required in order to obtain a reasonably accurate map of the Palaeozoic strata. As the reader will have noted, no Palaeozoic rocks have yet been found in the North Island.

It is hardly necessary to state that the Palaeozoic strata, except in Central Otago, where large areas of schistose rocks have gentle dips, are intensely folded. The strike, on the whole, is north-westerly, a feature well exhibited in some parts of Central Otago and near Ross, in Westland. In Nelson the strikes of the old rocks are very variable. The gneisses and schists along the western base of the Southern Alps, on the whole, have a north-north-east strike, which is therefore nearly but not quite parallel to the trend of the alpine range. Since block-faulting, accompanied by tilting, is prevalent in all areas of Palaeozoic (and of Mesozoic) rocks, the original strikes and dips in some cases may have been much altered, and therefore it may be surmised that the original strike in all localities was north-westerly.* That folding along north-west to south-east lines took place before the end of the Palaeozoic may be inferred from the fact that a north-north-east to south-south-west folding prevails in the Trias-Jura rocks of Canterbury, Marlborough, and the North Island south of Auckland.† Since the Maitai rocks of the Dun Mountain district also strike north-east, the Palaeozoic folding was probably pre-Permian. The fact that pre-Triassic floras, so far as known, are totally absent from New Zealand as now constituted cannot be held to prove that this country was wholly submerged during the pre-Mesozoic periods, seeing that in various places probable Palaeozoic strata contain conglomerates. During the Palaeozoic periods, then, New Zealand was at times the foreshore of a great continent (Gondwanaland), and at times probably formed part of the continent itself.

Mesozoic Rocks.

Mesozoic rocks are very well represented in both North and South Islands. The early and middle Mesozoic strata fall into one great Trias-Jura series (the Hokanui‡ system) which cannot as yet be subdivided by means of unconformities or lithological characters, and in many places

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* In *N.Z.G.S. Bull. No. 6*, 1908, p. 78, I have ascribed the irregular folding of the Arahura series in the Southern Alps to the distortion produced by compressive forces acting in a direction at right angles to the original folds.

† It is perhaps hardly necessary to advise the reader to be cautious in accepting statements of this kind. He will find that the views here advanced are not wholly consistent with the discussion on folding in *N.Z.G.S. Bull. No. 6*, pp. 35–37.

‡ Of late years this name has generally been spelt "Hokonui," but the older spelling "Hokanui" is retained in this paper and the accompanying maps.

is sparingly fossiliferous. There are also, however, many localities where fossils are sufficiently abundant and distinctive to enable broad zones to be established. Thus Newell Arber, working on plant-remains, has recognized Rhaetic floras at Mount Potts and Clent Hills, Canterbury; possible Rhaetic floras at Hokanui (or Hokonui) Hills, Southland, and at Owaka, Otago; Lower Jurassic floras at Malvern Hills, Canterbury, at Mokoia, (near Gore), and Mataura Falls, Southland; and an interesting Middle Jurassic flora at Waikawa, Southland. C. T. Trechmann, as the result of molluscan investigations, has distinguished a number of horizons, which he correlates with various European horizons. From the geological map it will be observed that Trias-Jura rocks occur extensively in Southland and south-east Otago, and that a broad belt stretches from northern Otago through Canterbury and Marlborough to Cook Strait. On the north side of the strait a continuous belt of Trias-Jura strata, not so broad as that in Canterbury and Marlborough, extends from Wellington to the neighbourhood of Cape Runaway. Many isolated but considerable areas of Trias-Jura rocks occur elsewhere in the North Island—for instance, north of Mokau River, at Kawhia Harbour, in the middle Waikato district, west of the Firth of Thames, near Coromandel and Cape Colville, in Great Barrier Island, near Whangarei, in the Bay of Islands district, &c.

The Cretaceous rocks of New Zealand do not form a natural unit. The Lower Cretaceous has been involved in the great post-Jurassic movements sometimes termed the post-Hokanui deformation, whereas the Middle and Upper Cretaceous follow these movements, and consequently are separated from the Lower Cretaceous by a strong unconformity. Had the science of geology originated in New Zealand, without doubt the Lower Cretaceous would not have been placed in the same system as the Middle and Upper Cretaceous. It is here, perhaps, that the European terminology fails more badly than at any other stage of New Zealand geological history. However, the groups of strata placed in the European Cretaceous are not altogether happily united, and the system appears almost as artificial there as it does in New Zealand.

Lower Cretaceous (Neocomian) rocks appear on the coast-line south of the mouth of the Waikato River. Here they contain numerous plant-remains, including a few dicotyledonous leaves. The much folded and distorted rocks seen at Awanui (south of East Cape) and along the east coast of Wellington are believed to be Lower Cretaceous. The so-called "cannon-ball" sandstone at Amuri Bluff, together with certain greywackes and sandstones in other parts of Marlborough, is also probably of the same age.

The rocks in the Middle Clarence and Upper Awatere valleys, Marlborough, containing a fauna described by Woods as of Lower Utatúr or Albian age, are here placed in the Middle Cretaceous (Clarentian of Thomson). It is admittedly not usual to introduce a middle division into the Cretaceous, but in some countries this course seems desirable. It has been adopted and defended by Haug in his *Traité de Géologie.*

Following the Albian beds, possibly with some degree of unconformity, is a very interesting group of strata, which forms the Waipara series of Hutton. At Amuri Bluff the Waipara beds consist of fine conglomerate, sandstone, greensand, &c., followed by a thick limestone which is almost devoid of molluscan remains, and is known in geological literature as the Amuri limestone. The lower beds, which form Thomson's Piripauan, contain a fairly rich molluscan fauna, identified by Woods and Wilckens as Senonian. This Senonian fauna has not been found in the Middle Clarence

Valley, where, however, the Amuri limestone is of great thickness (according to Thomson, 2,500 ft. if accompanying flint-beds be included). Hence Woods thinks there is an unconformity at the base of the Amuri limestone.

Other localities where the Senonian fauna is found are the Waipara district in North Canterbury, and the Malvern Hills district in Central Canterbury. Beds of nearly if not quite the same age occur above the coal-measures in the Shag Point district, Otago. The coal-measures of Green Island (south-west of Dunedin), and probably those of Kaitangata, must also be placed in the Upper Cretaceous. In the North Auckland Peninsula a Senonian horizon seems to occur, as is indicated by the ammonites Dr. Marshall has discovered near Batley, Kaipara Harbour.*

The age and correlation of the Amuri limestone have caused considerable discussion. This rock, as already mentioned, is of great thickness in the Middle Clarence district, but becomes thin in the Upper Clarence Valley. The thicknesses recorded by McKay at Kaikoura and Amuri Bluff vary, for some unexplained reason, from 260 ft. to 630 ft. In North Canterbury, according to Speight and Wild, its thickness varies from about 20 ft. or 25 ft. to at least 300 ft., and a thickness of only 5 ft. (in Omihi Creek) is recorded by Thomson. South of Mount Grey the Amuri limestone probably disappears, though a limestone closely resembling it in lithological characters occurs in the Trelissick Basin. Undoubted Amuri limestone outcrops on the south-east coast of Wellington some distance north-east of Cape Palliser. It has also been correlated with a similar limestone in the Gisborne district. Opinion has varied whether the Amuri limestone could be correlated with the widespread argillaceous limestone of North Auckland known as the "hydraulic limestone." Recent field-work by H. T. Ferrar, as well as the discovery by Marshall of a Senonian horizon in mudstone apparently underlying the hydraulic limestone, render it altogether probable that this rock is of Upper Cretaceous age, and therefore can legitimately be correlated with the Amuri limestone. The consensus of evidence points to a Danian age for these much-discussed rocks.

General Remarks on the Mesozoic Rocks.

As previously mentioned, all the Mesozoic rocks prior to Middle Cretaceous are involved in the great post-Jurassic or post-Hokanui deformation. They are, moreover, much affected, together with both earlier and later rocks, by late Tertiary block-faulting and tilting. In Otago and Southland the Trias-Jura rocks strike in general to the north-west; in Canterbury, Nelson, and Marlborough they have very variable strikes, more often to the east of north than to the west. Throughout the North Island the strikes are variable, but south of Auckland a north-north-east trend is certainly most prevalent. North of Auckland the average strike probably inclines decidedly to the west of north, in sympathy with the trend of the North Auckland Peninsula. These facts indicate that in the south, and possibly also in the extreme north, of New Zealand the folding was of the posthumous type, following already existing Palaeozoic folding, but in other localities it commonly took a new direction almost at right angles to the older. The two foldings may have met in an imperfect syntaxis in north-west Otago, and, if so, the Southern Alps must have first arisen at this time. New Zealand may be said to have begun an independent existence

* In a letter dated 29th March, 1920, Mr. Henry Woods states that the horizon of two of the collections made by Mr. Alex. McKay in the Whangaroa district (localities Nos. 106 and 750) is Senonian.

with the post-Hokanui deformation. Previously it was but the foreshore of the now dismembered continent, Gondwanaland. Henceforth, also, as Hutton has said, at no time was the whole of the present land area submerged.

Tertiary and Post-Tertiary Strata.

As mentioned in more detail under a later heading, Hector and McKay from 1877 (or even earlier) consistently maintained that in New Zealand there was no palaeontological or stratigraphical break between the Cretaceous and the Eocene. In consequence, the Geological Survey under Hector's regime officially incorporated a Cretaceo-Tertiary system in its classification. The officers of the present Geological Survey, however, have not been able to accept the old Survey's views. Strong evidence of a stratigraphical as well as a palaeontological break between Upper Cretaceous and Tertiary has accumulated during the past few years. The stratigraphical break, however, is nearly everywhere a disconformity or so-called erosion interval, and so far angular unconformity has been found only in the Gisborne district.

The following groups of strata are placed by the writer in the Eocene (Waimangaroan, or Mawheranuian): Greymouth coal-measures (except perhaps the Paparoa beds) and conformably overlying marine strata; Westport bituminous coal-measures, &c.; coal-measures of various parts of central Nelson (*e.g.*, Baton River); lower coal-measures of Collingwood district (?); Weka Pass stone and Grey Marl; Hampden beds.

The Eocene strata are separated by a mild unconformity from a series of beds which may fittingly be placed in Hutton's Oamaru series. This is separated by a slight unconformity, not everywhere detectable, from Hutton's Pareora series. In this paper the Oamaru and Pareora series are united to form the Oamaru system, in which stages known as Ngaparan, Waiarekan, Ototaran, Hutchinsonian, and Pareoran or Awamoan are recognized. In the Oamaru district the Hutchinsonian is separated from the Ototaran by a slight disconformity, whilst in other parts of New Zealand it cannot, as a rule, be clearly defined. Hence it might well be merged in the Pareoran stage.

In some parts of New Zealand there occur strata known by their stratigraphical position and molluscan fauna to be somewhat younger than the typical Awamoan, but not easily separable either from it or from the strata forming the lower part of the Wanganuian. These are the Awatere beds, and form what may perhaps be called the Awaterian stage, which, however, is at present not clearly definable, and must simply be considered as intermediate between Awamoan and Wanganuian. In this category come not only certain strata in the Lower Awatere Valley, but portions of the strata in southern and central Taranaki that conformably underlie undoubted Wanganuian, together with the Ormond limestone and Tawhiti beds of the Gisborne district.

Strata of approximate Pliocene age are usually referred to the Wanganui series, a term which may be linked with Hutton's name, though the term "Wanganui River beds" was used by Hochstetter. This series has a wide distribution in the North Island, more especially in the southern half. In Taranaki the Onairo series of Clarke falls partly in the Wanganuian, to which also belong the Petane, Scinde Island, and Te Aute beds of Hawke's Bay. In the Wanganui district the Wanganuian has been divided by Thomson into two stages, the Waitotaran and the Castlecliffian. In the South Island the marine representatives of the Wanganuian are found chiefly in North Canterbury (Greta and Motunau beds). In Nelson and

north Westland fluviatile strata of approximate Pliocene age are generally referred to as the "Moutere gravels." Similar gravels occur in North Canterbury, and possibly underlie the Canterbury Plain.

The Pleistocene and Recent strata of New Zealand include the morainic gravels of various parts of the South Island, the widespread river gravels and silts forming the surface of many of the plains, "raised beaches" (including Thomson's Hawera series), sand-dunes, &c.

Igneous Rocks.

The distribution of igneous rocks (including tuffs, &c.) in New Zealand is shown by the maps. Much has been written concerning them, and only a brief description can here be attempted. The oldest igneous rocks are probably represented by the gneisses of western Otago, which are largely metamorphosed diorites. In many places plutonic rocks intrude the Palaeozoic and Mesozoic formations, several of which also show evidence of contemporaneous volcanic action. Granite, intrusive into Ordovician and perhaps younger strata, occurs in Nelson, Westland, western Otago, and Stewart Island. It has, however, not been found *in situ* in the North Island, though in at least eight localities conglomerates containing boulders of granite and other plutonic rocks have been found. Ultra-basic igneous rocks, now largely altered to serpentine, occur somewhat prominently in north-west Otago, Westland, and Nelson, nor are they unknown in the North Island.

Throughout the greater part of the Tertiary periods volcanic action in New Zealand was more intense than in any former age. There is no clear evidence of Eocene vulcanism, but during the Miocene period eruptions, at first principally of andesitic rock, began in the Coromandel Peninsula, and with little intermission continued until somewhere about the end of the Pliocene. The later lavas were chiefly rhyolites. These volcanic rocks, more especially the andesites, contain metalliferous quartz veins which have yielded many million ounces of gold and silver.

There are many areas of Tertiary volcanic rocks in North Auckland, and near the City of Auckland numerous small volcanoes were active during the Pleistocene, some perhaps even within the last few thousand years. In Taranaki the Pouakai Range and the beautiful cone of Mount Egmont were formed during Pliocene and Pleistocene times. It is in the central part of the North Island, however, that the most intense volcanic activity has been displayed. Igneous rocks, and more especially pumiceous material ejected during the Pleistocene, cover large areas. The numerous steam-vents, hot springs, and geysers in the belt of country extending from Mount Ruapehu to the north side of Lake Rotorua strongly suggest volcanic forces to the visitor. Solfataric action is generally regarded by geologists as a sign of dying vulcanism, but this opinion may not always be correct. Vulcanism has certainly not yet ceased, for minor eruptions of fragmentary material still take place from Ngauruhoe, a typical volcanic cone near Mount Ruapehu, and from White Island, in the Bay of Plenty. On the 10th June, 1886, an apparently extinct volcano, Mount Tarawera, burst into eruption, with the result that 130 lives were lost. In September, 1914, an eruption at White Island was fatal to the eleven sulphur-miners who were on the island at the time. The great Waimangu Geyser in 1903 overwhelmed four persons; and fourteen years later a true volcanic eruption at Frying-pan Flat, close to the now quiescent geyser, caused the loss of two lives. These catastrophes indicate that a close study of the volcanic

phenomena of the "thermal" region, if it will contribute in any way to the saving of human lives, is something more than a scientific desideratum.

In the South Island vulcanism is apparently quite dead, for the hot springs found in many localities are not signs of subterranean lavas, but are due in all cases to heated water rising up fault-planes. During the Miocene, however, volcanic outbursts took place in many localities—in some on a grand scale. Banks Peninsula is formed mainly of basaltic and andesitic rocks. In the neighbourhood of Dunedin occurs a very interesting series of alkaline volcanic rocks, which have been described by G. H. F. Ulrich, P. Marshall, and others.

The Cretaceo-Tertiary Hypothesis and the Ages of New Zealand Coalfields.

The term "Cretaceo-Tertiary," so far as I know, first appeared in Hector's *Abstract Report on the Progress of the Geological Survey of New Zealand during 1866–67*, p. 8, 1867.* In his *Progress Report, 1868–69*, p. v, 1869, Hector states that the coal-measures of Morely Creek,† Preservation Inlet, Shag Point, west coast of Nelson, Waikato, and Bay of Islands all "belong to a period which, in some respects, must be considered as intermediate between the Chalk and Lower Tertiary formations." His geological map of 1869, which was prepared in 1866, also shows a Cretaceo-Tertiary formation. The Cretaceo-Tertiary hypothesis is again outlined, though not distinctly stated, in Hector's lectures "On Mining in New Zealand" (*Trans. N.Z. Inst.*, vol. 2, pp. 361–84, 1870). Hector says (p. 363) that "the sequence of geological formations in New Zealand is abruptly broken about the close of the Lower Mesozoic period," and then he describes in general terms (pp. 364–65) the later formations, which are grouped together, and clearly correspond to Thomson's Notocene. In 1872 Hector stated that he had applied the term "Cretaceo-Tertiary" to certain groups of strata, "as no well-marked break that is common to all the sections that can be inspected has been observed in their sequence; and, moreover, certain fossil forms are found in all the members of the series" (*Trans. N.Z. Inst.*, vol. 4, pp. 344–45). The legend or reference on Hector's geological map of 1873 contains "Marine Tertiary (Pliocene-Cretaceous)" and "Coal Formation (Miocene-Cretaceous)." In his *Progress Report, 1876–77*" (*Rep. Geol. Explor.*, No. 10, 1877), Hector gives (pp. iii–v) a "new classification, which is compared with the classification in the geological map of 1873, and Hutton's classification of 1875 (*Geology of Otago*, p. 26). Here the Cretaceo-Tertiary grouping received practically its final form so far as the Geological Survey was concerned.

According to Park (*Geological Magazine*, dec. v, vol. 9, p. 491, 1912), Hutton was the originator of the Cretaceo-Tertiary hypothesis; but this seems incorrect, for Hector in 1872 claimed the term "Cretaceo-Tertiary" as his own, whilst Hutton does not include it in his classification of 1873, and from 1875 onwards strongly opposed it. In 1905 he gained the support of Park, and thereafter the Cretaceo-Tertiary hypothesis seemed to be in a dying condition. In 1911, however, it was revived in a slightly different form (practically that of Hector's geological map of 1869) by Marshall, Speight, and Cotton, who maintained that no unconformity could be detected between Upper Cretaceous and the Pliocene, and that palaeontologically there was a more or less gradual passage from Cretaceous to Eocene. The field-work of the present Geological Survey, however,

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* A second edition of this report was published in 1868.
† Now known as Ohai Creek.

has shown that unconformities (generally not markedly angular) abound in the supposed conformable series. The palaeontological work of Woods, Suter, Thomson, Trechmann, Wilckens (not yet published), Chapman, and Marshall himself shows that there is a marked palaeontological break, as Hutton maintained, between Cretaceous and Tertiary rocks. Marshall, Speight, and Cotton's paper of 1911 has directly and indirectly provoked a great amount not only of controversy, but of research, both stratigraphical and palaeontological. Hence, though its leading conclusions have been successfully assailed, it must be regarded as a most valuable contribution to the geological literature of New Zealand.

The "Cretaceo-Tertiary" controversy, which has continued from 1875 to the present day, had its roots in the important fact that nearly all the workable coal of New Zealand is found in Hector's Cretaceo-Tertiary formation. Obviously the geology of the coal-measures is a matter not merely of academic interest, but of great economic significance, and therefore no compromise between the hostile views could be made. From 1877 onwards the official view of the old Geological Survey was that workable coal, with a few unimportant exceptions, occurred only at or near the base of the Cretaceo-Tertiary. Hutton, on the other hand, maintained that the Cretaceo-Tertiary coal-measures fell into four groups. It is now certain that his views, both of the geological classification and of the grouping of the coal-seams, were far nearer the truth than Hector's. According to our present knowledge, coal occurs in the following post-Hokanuian horizons:—

(1.) Upper Cretaceous (Senonian): Waipara (Boby's Creek), Malvern Hills, Shag Point, Green Island, and probably Kaitangata.

(2.) Early Eocene, or possibly very late Cretaceous: Paparoa beds, Greymouth. At present included by me in the Mawheranuian.

(3.) Eocene (Mawheranuian): Greymouth, Westport (bituminous coal), central Nelson, Collingwood (in part) (?), Paringa River (probably).

(4.) Early Oamaruian (Ngaparan): Whangarei, middle Waikato (Huntly), Collingwood (in part), Charleston, Brighton (Westport), Inangahua (in part), South Canterbury, Oamaru, Waikaka, Waikaia, Nightcaps or Wairio (?), Central Otago (?).

(5.) Pareoran, or Awamoan: Mokau River, Tangarakau Gorge, Retaruke River, Inangahua (in part). Just possibly the Central Otago lignites belong about here.

(6.) In various places there are lignites of Pliocene age (as always admitted).

CONCLUSION.

In the preceding pages a certain amount of discussion has been introduced which would have been omitted if the intention with which this paper was started had been rigorously followed. Various points which receive scanty attention are adequately presented in Dr. Benson's presidential address delivered last January to Section C of the Australasian Association for the Advancement of Science. References to the literature have not always been given, since it was known that these would be found in Dr. Benson's address. Owing to the amount of stratigraphical and palaeontological research now going on in New Zealand, the sketch-maps presented with this paper will require some modification before long. The same remark may be made concerning the appended tables showing geological classification.

TABLE I.—CLASSIFICATION OF CRETACEOUS AND TERTIARY STRATA.

Approximate Age.	Series or System.	Stage and Group Names (Adjectival Forms).	Northern Auckland.	South-west Auckland, Taranaki, and Wanganui.	East Coast of North Island.	Marlborough and Canterbury.	South Canterbury and Otago.	Nelson and Westland.
Pliocene.	Wanganui series or system (Wanganuian).	Castlecliffian or Petanian.		Castlecliff beds; Kaawa Creek beds.	Petane and Scinde Island beds (Napier series).	? Great Marlborough conglomerate; Awatere beds (part); Greta and Motunau beds.		
		Waitotaran.		Waitotara beds. Onairo and Tongaporutu series, &c.	Te Aute series. Ormond limestone.			Deltaic beds of Inangahua-Grey valley.
Miocene and Oligocene.	Oamaru system (Oamaruian).	Pareoran (Awamoan).	Waitemata and Orakei Bay beds.	Mohakatino, Mokau, and Mahoenui beds.	Tawhiti series.	Part of Awatere beds.	Pareora and Awamoa beds.	Blue Bottom and Upper Kongahu beds.
		Hutchinsonian.					Hutchinson Quarry beds.	
		Ototaran.	Whangarei limestone.	Raglan and Te Kuiti limestones, &c.	Te Arai series (8,000 ft. thick).	Mount Brown beds, &c.	Ototara limestone.	Cobden limestone and Lower Kongahu beds.
		Waiarekan.		? Leda Marls, &c.			Waiareka beds.	Port Elizabeth and Omotumotu beds.
		Ngaparan.	Whangarei coal-measures.	Waikato (Huntly) coal-measures, &c.			Ngapara beds.	? Reefton coal-measures.
Eocene.	Mawheranui or Waimangaroa series (Mawheranuian).	Kaiatan.	? Part of Kaeo series; ? Tiger Hill sandstone.		? Wheao series.	Grey Marl of Weka Pass; Weka Pass stone.	Hampden (Onekakara) beds.	Kaiata beds.
		Islandian.						Island sandstone.
		Brunnerian.						Brunner beds.
		Paparoan.						Paparoa beds.
								Hawk's Crag breccia.

		"Atiuian."	Part of Kaeo series; Hydraulic limestone.		Mangatu series.	Amuri limestone.		
Upper Cretaceous (Danian and Senonian).	Waipara series or system (Waiparan).	Piripauan (Thomson, 1917)	Part of Kaeo series; Ammonite beds, Batley (Marshall, 1917)			Saurian beds; Belemnite beds, &c.	?Wangaloa beds and Kaitangata coal-measures. ? Shag Point beds=Makatea (Hutton, 1885) or Pukeiwitahi beds.	
Middle Cretaceous (Albian or Cenomanian).	Coverham, Waiautoa, or Clarence River series.	Clarentian or Waiautoan.				Coverham, Waiautoa, or Clarence River series.		
Lower Cretaceous (Neocomian).	Port Waikato plant beds			Port Waikato plant beds.		? "Cannon-ball" sandstone of Amuri Bluff.		
	? Awanui beds.	Awanuian.			? Awanui beds.			

TABLE II.—CLASSIFICATION OF PRE-CRETACEOUS STRATA.

Approximate Age.	Series or System.	Group or Alternative Names.	Chief Localities, &c.
Jura-Trias.	Hokanui system.	Mataura series (Jurassic); Putataka series; Catlin's River series; Flag Hill series; Bastion series; Otapiri series; Oreti series; Wairoa series (Triassic); Kaihiku series; Mount St. Mary series; Aorangi series; Manaia Hill series (Jurassic); Moehau series; Tokatea series; Waipapa series, &c.	Waikawa (Middle Jurassic); Mokoia Farm and Mataura Falls (Lower Jurassic); Malvern Hills (? Lower Jurassic); Owaka (? Rhaetic); Hokanui Hills (Rhaetic and younger); Kaihiku; Clent Hills and Mount Potts (Rhaetic); Nugget Point; Mount St. Mary; Wairoa Valley (Nelson); Wellington district; Awakino; Kawhia; Coromandel district; Whangaroa district, &c.
Permian or Permo-Carboniferous.	Maitai series.	? Part of Arahura series.	Dun Mountain district; ? Taylor's Pass (Marlborough).
Late Palaeozoic.	Te Anau series.	Haupiri series; Pelorus series; Kakanui series.	Western Central Otago; Collingwood district; Pelorus Valley; North-east Otago (Kakanui series).
Silurian (Wenlock).	Wangapeka series.	Baton River series; Reefton beds or series.	Baton River; Reefton (so-called "Devonian" beds).
Ordovician.	Aorere series or system.	Greenland series; Wanaka system of Hutton; Part of Manapouri system of Park; ? Part of Arahura series.	Collingwood district; Reefton; Paparoa Mountains; Ross; Preservation Inlet; ? Otago schists, &c.
Pre-Ordovician.	Manapouri series.	Manapouri system of Marshall; ? Part of Aorere series; Part of Manapouri system of Park.	North-west Nelson and Western Otago (gneisses, &c.).

NATURAL-HISTORY NOTE.

Note on the Feeding-habits of the Shining Cuckoo, by R. E. Grimmett.

While visiting Nelson last Christmas I was fortunate enough to make the following observation :—

Just below the Nile Street Bridge (over the Maitai River) there is a steep bank covered with the so-called "native ivy" (*Senecio mikanioides*) lying beneath the willows which line the bank of the river. The plant was swarming, as usual, with the hairy black-and-yellow larvae of the black-and-white moth *Deilemera annulata*. Perched on a willow-twig about 10 yards from where I was standing, a shining cuckoo (*Chrysococcyx lucidus* Gm.) was making the air vibrant with his very characteristic song. He was in plain view, and so there was no possibility of mistaking his identity. Presently he dived abruptly into the mass of "ivy" and returned carrying a larva. This he devoured at leisure. He repeated the process three or four times, and was seen picking the larvae off the leaves. These larvae are distasteful to most birds, and in consequence, perhaps, of the immunity they enjoy feed in full view on the upper surface of the leaves. In this position they are very conspicuous objects, and so the bird could easily be seen in the act of picking them off. He seemed quite to enjoy his meal, pausing every now and then to pour forth his song. Altogether I had him under observation for some ten minutes, when he took flight and went farther down the river.

The above observation is in concordance with the habits of the Cuculidae in other countries, where they are frequently observed to feed on hairy lepidopterous larvae which are distasteful to other birds.

REVIEWS AND ABSTRACTS.

Statistical Supplement to the Final Report of the Nitrogen Products Committee of the Ministry of Munitions, compiled by J. A. Harker. H.M. Stationery Office, London.

In the Final Report of the Nitrogen Products Committee of the Ministry of Munitions the results of a detailed examination of the whole problem of nitrogen fixation are given. As the report was prepared during the war the statistics did not cover the latter part of the war and the period which has elapsed since its termination. In this supplement the statistical information is brought up to date. Considerable space is devoted to Chile nitrate, the price of which determines the price of the other nitrogen products. Tables are given showing the British prices and imports, the amounts allotted for fertilizer and munition purposes respectively, and also the world's consumption during the war period. At the present time it comprises 30 per cent. of the world's output of nitrogen compounds. Ammonium sulphate, recovered as a by-product in the gas and coke industries, amounts to 26 per cent. of the output. The fixation industries expanded wonderfully during the war period. In 1912 their output was equivalent to only 32,000 metric tons of nitrogen, or $4\frac{1}{2}$ per cent. of the world's production. In 1920 they were capable of producing 670,000 tons, equal to 43 per cent. of the world's total

Electric-arc processes, developed chiefly in Norway and Sweden, were responsible for 38,000 tons, or 2½ per cent. of the total. The cyanamide process, mainly electrical, was used increasingly during the war period in France, Germany, and the United States of America. Though considered by some to be obsolete, it is still credited with 21 per cent. of the world's output.

The synthetic process, in which ammonia is produced by the direct union of nitrogen and hydrogen, produced 20 per cent., almost as much as the cyanamide process. It originated in Germany, and has been chiefly developed there. The works at Oppau, which were destroyed by the disastrous explosion in September last, had an output of 250 metric tons of ammonia per day. Those at Merseburg are still larger, being capable of producing 800 tons each day.

In Great Britain a factory commenced at Billingham by the Ministry of Munitions in 1918 has been taken over by Messrs. Brunner, Mond, and Co. The present plant is designed for a daily output of 25 tons of ammonia, but is capable of expansion up to a maximum of 300 tons.

The world output of nitrogen products has more than doubled since 1912. The huge demands created by the war were responsible for this, and it is as yet difficult to estimate what the post-war demand will be. Consumption, however, for fertilizing purposes has largely increased in many countries, and there are indications that, rapid as the expansion in production has been, the demand for fixed nitrogen is growing at an even greater rate. W. D.

Tutira: the Story of a New Zealand Sheep-station, by H. Guthrie-Smith. William Blackwood and Sons, Edinburgh and London, 1921. 400 pp.

In this work we have an entirely new departure in the recording of reminiscences by an old settler. A number of books have been written with this aim, but they are not striking productions; in some cases the arrangement of data is poor—the writers have not possessed the faculties of assimilation and methodical adaptation. Mr. Guthrie-Smith's book stands apart from all other such works. The haphazard mode of recording finds no place in his scheme of work. A perusal of *Tutira* leaves the reader in a condition of admiration for the indefatigable collector of data over a long term of years. His powers of observation and keen interest in nature, in his work, in apparently all things around him, bring much pleasure to the reader.

This is the first time that the breaking-in of new country in New Zealand has been well described, and herein we see every detail of the long process. Had the lands described been of first-class soil the work before us would have lost much of its interest. Here we have in detail an account of the long fight against poor soil, against fern, against *manuka*, against low prices, that often seemed so hopeless. Numbers of the early runholders of the eastern side of the Island went through that long fight in which many were defeated.

The author commences his task with some account of the Tutira district, the configuration of the land, its geological formation, soils, hills, vales, streams, and lakes; its original condition, the changes wrought by the coming of the Maori, and some data concerning Maori occupation of the district, are all included in the story of Tutira. A large number of native place-names have been preserved, which the author does not attempt to translate—a wise decision. The note on an artificial island retreat or

pa is interesting, though the illustration of Tauranga-koau is somewhat puzzling. A pleasing feature is the fact that errors in the spelling of native words are much less common than in most works written by settlers. "Omaranui" for "Omarunui" is an almost universal error, but "*houtawai*" for "*hutiwai*" is startling. The tale of Te Amohia slaying the Tuhoe warrior and taking his heart to perform the *whangai hau* rite reminds us how few generations separate us from such stirring scenes.

The unstable nature of the land surface at certain places on the eastern coast is illustrated by the remarks on landslides and extensive creeping, while the abominable underground drains were a ceaseless nuisance to the old bullock-punchers of that coast. Of much interest is the evidence as to former forest growth in huge trunks of *totara* found on the surface, and on the reafforestation by nature when not baulked by fire. In this writer we have a keen observer of variations of plant-growth and the habits of animals, an enthusiastic naturalist, a tireless note-jotter of what are to most folk trivial details. The life-story of the *totara* at p. 99, that of succession and displacement of species, the remarks on seed-distribution, on grassing, on the local flora, introduced plants and animals, on birds, on the habits, movements, and migrations of animals, on melanism in merinos, &c., all witness the truth of the foregoing estimate.

No man has told of the genesis of a sheep-station as has this writer. Those who have lived the life described in *Tutira* in the "seventies" and "eighties" will bear me out in this statement. Truly our memories swing back to the rough slab huts of those days and the fried chops in the camp-oven referred to by the writer at p. 121. Those were the days of meat, bread, and tea; of working until dark, then coming home to cook meat and bread in the capacious fireplace. Yet, in poverty and heavy toil, the joy of life was with us, as shown at p. 131.

The story of our station is not always pleasant reading, but it holds its interest throughout. It is a story of a long fight against nature and poverty, of a great and enduring faith, of patience and determination The frequent changes of owners in early days tells its own tale. Lack of feed for stock, low prices, ignorance of local conditions and requirements, unsuitable breeds, foot-rot, and financial anxieties—all these, added to unkindly soil, spell out the tragedy of many lives. As one difficulty was overcome another presented itself. And yet with ceaseless work and ceaseless anxiety our author always found time to study the phases of nature around him, the life-story of all living creatures, the habits of plant-life, the ever-changing aspect of the old Earth Mother. The exasperating mishaps of post-packing, the disheartening losses of stock, would weigh less heavily on the man who could find interest and cheer in all things that live in the world of life. Though one eye was ever doubtless kept on a slim bank account or the grave face of the banker, yet old Terra Mater doubtless made amends in many ways to the sheep-farming naturalist.

The pleasure experienced by the author on having made a good job of erecting a wire fence (p. 234), and his account of burning off fern that follows, will appeal to many stiff-jointed old pioneer workers, though hardly to present-day workers.

The work contains a number of interesting illustrations, and also many diagrams. Some of these latter illustrate the formation of paths by sheep, their curious irregularities, with the origin of the same, the sheep "viaducts," the peculiar and aggravating tracks made by horses on wet ground, and many other things. Such observations are invariably correct,

but how very few there are who would ever dream of putting such observations on record. It is the faithfulness of the accounts of these more trivial things that makes the book such enjoyable reading to those who have lived that life.

The illustrations of the homestead of the "eighties" (p. 150) and that of late days (p. 382) are sufficient to tell that, after much toil and many years anxiety and tribulation, the end was well.

Tutira is a remarkable book, a fascinating and useful work containing a great deal of curious and interesting information now for the first time recorded. Nothing pertaining to the station seems to have been omitted, save perhaps the earthworms. Old-time veterans of the fern lands and modern land-breakers alike will be well advised to peruse it.

E. B.

Economics of Hydro-electric Development, by A. H. Gibson. *Engineer*, 8th and 15th April, 1921.

This article, which covers in some twelve columns the whole range of the subject, is difficult to abstract without loss of essentials, but in view of the general public interest of the subject an attempt is made.

The economic development of a hydro-electric station depends on (*a*) a market for the power, and (*b*) the price at which power can be sold. These two are interdependent, as on the demand and load factor the price largely depends, and a low price for power will attract industrial loads.

For a hydro-electric development without storage the available power from the river will be represented by the hydrograph of the river. The station may be designed (*a*) to utilize the minimum dry-weather flow, (*b*) to utilize the average dry-weather flow, or (*c*) to utilize more than the average dry-weather flow. In cases (*b*) and (*c*) the deficiency of power may be met by installing fuel-stations of low capital cost and low efficiency. These should be regarded as an integral part of the hydro-electric development. However, if the market is suitable, the station may be designed for more than minimum dry-weather flow and contracts entered into for the supply of power during certain months only. The capacity to install in hydro-electric station without storage depends on, *inter alia*, the hydrograph of the river, the relative costs of headworks and generating plant, cost of fuel-stations, cost of fuel, and the nature of the market.

A controlling feature in the design of all generating-stations is the diversity factor, which is quoted as having a range of 1·25 to 2·4, with a mean of 1·6, for industrial loads.

The importance of lighting and other night loads is pointed out.

Figures are given for power-consumption for electro-chemical processes, and the limitations due to freight and transport conditions are dealt with. The following table is of interest:—

Aluminium	3·2	kw. per annum per ton.
Abrasives	1·5	,,
Calcium carbide	1·0	,,
Pig-iron smelting	0·25	,,

Loads such as these are essentially of high load-factor.

The cost of hydro-electric power is primarily a function of the capital cost of the installation. The capital cost includes: (1) Preliminary investigations, promotion, and organization; (2) land, water rights, and right-of-ways; (3) constructional work and plant; (4) engineering; (5) interest during construction. Interest charges are the main cost of a

hydro-electric development, and hence for a given size of station the cost per unit is almost inversely proportional to the output. Therein lies the importance of an adequate market for the power.

Operating-expenses may be divided broadly as follows: (1) Wages and supplies; (2) supplies; (3) repairs and maintenance; (4) depreciation. Generally 0·5 per cent. may be taken as covering repairs and maintenance on hydraulic works and buildings, and 1·5 per cent. on the capital costs of machinery and transmission-lines.

Depreciation is the most important item in the operating-expenses, and the following rates are suggested:—

	Per Cent.
Civil-engineering works	1·5
Pipe-lines	2·5
Electric equipment	4·0
Turbines	4·5
Transmission-lines—	
Towers	3·0
Cables	5·0
Insulators	10·0
Operating machinery in power-house, cranes, &c.	6·0

In the majority of cases this works out at from $2\frac{1}{4}$ to $3\frac{1}{2}$ per cent., depending on the relative costs of the civil, mechanical, and electrical engineering portion of the work.

Capital and operating costs for Swedish stations are given. Curves are given showing the capital cost per b.h.p. in relation to the size and also in relation to the head. The cost of these undertakings is distributed in about the following proportions:—

	Per Cent.
Headworks	75
Electrical equipment	16
Turbines and accessories	9

Running-costs average as follows:—	Cost per B.h.p. (Shillings per Year).
Administration	1·91
Staff for machines	2·44
Staff for distribution	0·72
Oil and stores	0·59
Fuel for stand-by running	2·06
Repairs and maintenance	1·98
Water rights and rent	0·27
Insurance	0·21
Rates and taxes	0·79
Incidentals	1·18
	12·15

Excluding fuel and distribution, this figure becomes 10s. per b.h.p. per year.

These figures, however, are very variable, and curves are given showing the relation of operating-costs to size of installation.

To summarize, the total cost of power may be taken as made up as follows: (1) Interest on total capital outlay; (2) a percentage charge varying from 3 to 3·3 per cent. on the capital outlay to cover repairs, maintenance, and depreciation; (3) an annual charge per turbine horse-power installed,

to cover all other working-expenses. This last charge varies greatly with the size of the installation and the amount of transmission and distribution.

Excluding transmission, and taking interest at 6 per cent., the total annual charges approximate 9·5 per cent. for a number of Canadian, American, and European installations.

The relative costs of hydro stations designed for low and high power-factors are considered, and a comparison is made with the fuel-burning plants.

The combined operation of hydro and steam plants as affording probably the most economical source of power in many cases is considered, as well as the use of stand-by plants.

The remainder of the article gives the actual costs of several stations, and also the estimated cost for several others. Costs are given for transmission, and the cost of power to the consumer for Canadian conditions.

I. R. R.

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THE COMMERCIAL ASPECT OF WATER-POWER DEVELOPMENTS IN NEW ZEALAND.*

By W. LANCELOT MOORE, A.M.Inst.C.E.

My object in reading this paper is to promote discussion upon the relative merits of big central power-stations, involving long transmission-lines and heavy initial expenditure, and of small and medium-sized stations situated near the power-markets, involving ultimately a greater capital outlay than the former but being far more suitable for a progressive or step-by-step development.

We are constantly reading accounts of what is being done in other countries, but I am sure it will not be questioned that installations which may be fully justified and economically sound in countries which are closely populated and have large industrial centres may be quite unsuitable for New Zealand, where the population is small and scattered, and where no important industrial centres exist.

I have been much interested in the Government's proposals with regard to water-power developments, but after consideration of the same am inclined to think that they are too ambitious, and that most of them are too big for this country in its present state of development. Mr. Parry, when making his report, no doubt intended it to be considered as a foundation upon which to build up the hydro-electric-supply systems of the Dominion, and as a guide to those carrying out smaller works in the meantime, so as to ensure that such works shall be designed to fit in with his ultimate scheme, which would only be installed when the country has reached that stage of development which would ensure its being a success financially instead of a burden.

I hope, therefore, that the discussion of this paper, as well as the figures which will come later, will be of service to the Public Works Department and to the country generally, by drawing some attention

* A paper read before the Technological Section of the Wellington Philosophical Society, 16th November, 1921.

away from the few schemes now being considered by the Department, and turning it towards the discovery and investigation of new ones; for it cannot be denied that in a country like New Zealand there must be hundreds of good medium-sized schemes to choose from, and a proper investigation of these might show them to be as good or even better than the large ones which are now contemplated.

New Zealand is at a very great disadvantage in not being in close touch with the progress in hydro-electric engineering, for she is so far away that her engineers have little chance of seeing for themselves what is being done in other countries, and have to rely solely on text-books and various engineering and technical journals. This is very apt to give them an unbalanced view of the situation, for we find as a rule that the only plants which are described in these journals are those which are of special interest by reason of their size or of some unusual feature, so that the man who reads these journals does not always realize that for every large plant which he sees described there are at least some hundreds of small and medium ones installed, as any large turbine-manufacturer could tell him. I therefore think that money would be well spent by the Public Works Department in sending their engineers abroad to study modern developments in other countries.

It is a very common belief amongst those who have not studied the question that the larger the plant the cheaper it will be. This does not always apply, partly because it is generally found that the extra-large plants are situated a long way from their markets, making transmission very expensive, but mainly because partial development of a large plant is nearly always costly, and during the early stages the installation is loaded up with interest, depreciation, and maintenance charges on work which will not produce any revenue until the final development is completed.

As instances that the biggest jobs are not always the cheapest, as well as of the other points mentioned above, we may take two examples from the Government proposals—namely, Waikaremoana and Arapuni.

At Waikaremoana it was originally proposed to put in a station with a head of about 600 ft., and later on to carry the pipes farther up the hill, doubling the head and consequently the power. On investigation, however, it was found that it would probably be cheaper to install and operate two separate stations, and that on the final development, after allowing for the operation of two stations instead of one, a saving of many thousands of pounds might be effected. This is explained by the fact that the pressure on the lower section of the pipes is twice as much with the higher head, necessitating an increase in the thickness of the pipes, and this would mean an average thickness in the lower section of $\frac{3}{4}$ in. instead of $\frac{1}{4}$ in. The saving in the pipe-lines alone by using two stations instead of one, and so breaking down the pressure, would be 2,000 tons of steel, which would mean a saving of about £100,000.

At Arapuni it has been proposed to erect a dam about 160 ft. high to divert the water into an old channel, down which it will flow to the intake-pipes and turbines. It appears as if this channel has been rather misleading and has drawn attention away from a series of low-head developments similar to that at Horahora, which could easily replace it, and would provide the progressive development which is so necessary in a country where the demand for large blocks of power does not exist. In all probability such a series of low-head developments would in the aggregate cost very little more than one big scheme, while the advantage is very much in favour

of the small schemes when partial development of the proposed 160,000 horse-power is considered. A further advantage is that, as there is every probability of a gradual decline of prices during the next ten years or more, it is not advisable to spend more than can possible be helped on work which is not immediately productive.

The main feature of the proposed Arapuni development is the dam, which is to be about 160 ft. high, and, owing to the nature of the country, will probably be of the gravity type. Now, the area of cross-section of a gravity dam is given very approximately by the area of a triangle of which the base is proportional to the height; and supposing the rapids were developed in stages by building four dams each 40 ft. high, the same total amount of power would be available—namely, 160,000 horse-power. But instead of one large station there would be four of 40,000 brake horse-power each; and, if the length of the dams are the same, each small dam will require only one-sixteenth of the amount of concrete that the big one does, and the four small ones together will only take a quarter as much.

It must be understood that this suggestion is given merely as an illustration of comparative costs, and it is not intended to advocate low-head schemes in the gorge itself, as it is doubtful if such would be possible; but there are many other places on the Waikato River where low-head schemes such as suggested could be installed.

It has been estimated that the 160 ft. dam will require 80,000 cubic yards of concrete. The approximate cost would then be as follows: 80,000 cubic yards concrete, £240,000; preliminary work and foundations, £120,000: total, £360,000. The approximate cost of four dams 40 ft. high and having an average length twice that of the high dam: 40,000 cubic yards concrete, £120,000; four coffer dams and foundations, £60,000: total, £180,000. These figures show a saving in the low-head schemes as follows: On the 160,000 h.p. development, £180,000, or £1·12 per horse-power; on the 80,000 h.p. development, £270,000, or £3·38 per horse-power; on the 40,000 h.p. development, £315,000, or £7·90 per horse-power. The average cost of turbines of 10,000 h.p. each is about £2·4 per horse-power for 160 ft. head, and about £3·8 for 40 ft. head, or £1·4 per horse-power in favour of the big scheme. The canal, intake, pipe-lines, &c., for the main scheme would cost at least as much, and probably a good deal more, per horse-power than the forebays and turbine-sumps for the lower-head schemes. Besides which, more than half the total cost of this section under the final development would have to be provided for a partial development.

The net result is, therefore, that if the full 160,000 h.p. from Arapuni could be sold at once it would certainly pay to put in the big scheme, so as to save operating-expenses of three extra stations; but unless the whole of the power could be sold from the start it will almost certainly be cheaper and more economical to put in several low-head schemes each large enough to meet the prospective demand for power at about the date of completion.

New Zealand, as we all know, is very rich in water-power, and with the exception of the west coast of the South Island, where the bulk of it is found, this power is fairly evenly distributed throughout the Dominion. Out of all the schemes which are available there must be a large number which can be very cheaply developed—at any rate, up to a limited amount, sufficient to meet the demands of the neighbourhood during the next fifteen or twenty years; and, moreover, they will in many cases be found fairly close to the area which they are to supply, thus doing away with expensive long-distance transmission-lines.

As I have already mentioned, one of the chief objects of this paper is to emphasize this point, as well as to point out that with the present state of population and industry in New Zealand it is probable that electricity can be more cheaply supplied throughout the country by a number of small- and medium-sized stations with short and local transmission only, with steam or oil for those places which are too far away, than by transmitting power all over the country from a few large stations.

In the meantime, local installations such as suggested above will build up a load and create a demand throughout the country for power-supply on a larger scale, thus ensuring the success of the large Government schemes when they come along—say, twenty years later—at which time the cost of the local schemes will have been repaid by a proper depreciation fund and the entire plant can be scrapped without any loss.

By pushing the local schemes in this way the people directly concerned with the supply of power in any particular area will be actively interested in the development, and will naturally push it to the best advantage, so far as that area is concerned, and political influence, which is such a handicap to all Government undertakings, will be removed. In addition to this, the local people will be encouraged to discover and investigate water-power schemes all over the country, which cannot but be an advantage to the community as a whole.

It may be argued that a number of small water-power schemes which have been installed in New Zealand have failed through insufficient supply of water all the year round. This, however, could only have been expected, and until more data regarding the run-off from different classes of country is available every scheme which is undertaken must be based more or less upon guess-work, so that there is just as much chance of the big schemes failing as the small ones, except on just those few rivers where a record of the flow during the last few years has been kept. It is therefore absolutely necessary, if the best results are to be obtained from the rivers of New Zealand, that a proper system of gauging should be instituted. This work can only be carried out efficiently by the Government. The country should be divided into areas having the same physical and geographical characteristics, and continuous records of the run-off from typical water-sheds, together with the rainfall, should be made. When this has been done for a few years data will be available which will enable the engineer, after a study of the watershed of any stream, to predict with reasonable accuracy what its capabilities are as regards power-supply.

In order to prove my contention that a group system with a large number of small- and medium-sized stations scattered throughout the country with local distribution only is at the present time better for New Zealand than the large central schemes with hundreds of miles of high-tension transmission-lines, it would be necessary to examine hundreds of schemes throughout the Dominion, and to compare their cost with the cost of the big central schemes. This work would take some years to complete, as there is little or no data available upon which to base even approximate estimates.

But, although my contention cannot at present be proved, it can easily be illustrated by means of actual figures obtained in other countries, where stations of different types and sizes have been installed in sufficient numbers to give reliable figures for the average cost per horse-power for each type or size. For this purpose I propose to make use of figures obtained in Sweden, where accurate records have been kept for a number of years, and where a large amount of information regarding actual costs

has been published. Sweden is comparable with New Zealand, for its area is one and three-quarter times and its population about five times that of New Zealand. At the end of 1917 it had developed 0·18 h.p. per head of population from water, and 0·08 h.p. per head from fuel plants, a total of 0·26 h.p. per head.

In 1910 the Swedish Government established a Water-power Control Board, who, with the existing Hydrographic Department, commenced a detailed survey of the water-power resources of the country. This work is still going on, and will take many years to complete. It is estimated that the unregulated flow of all the rivers is capable of supplying 6·2 million brake horse-power. Of this, 1·1 million horse-power had been installed at the end of 1917, and extensions up to 3·5 million horse-power were in sight and will probably be completed within the next fifty years.

Development of water-power on a large scale began about 1900, this having been made possible by the improvements in transmission of electric power. In order to encourage iron-smelting, steel-refining, electro-chemical and other industries which needed cheap power in bulk, the Government in 1902 commenced work on three big stations—Trollhattan, Alfkarleby, and Porjus—all of which are now in operation.

Practically all the power from Trollhattan (180,000 h.p.) is sold for industrial purposes. Transmission-lines radiate to a distance of seventy to eighty miles, and the area has become one of the most important electro-chemical districts in the world.

Power from Alfkarleby (70,000 h.p.) is transmitted to cities, towns, and farms over a large area, 120 miles long by 70 miles wide, round Stockholm. This area is devoid of water-power, but is one of the principal industrial areas of Sweden. There are numerous large steam stations connected into the system, and a branch line enables connection to be made when desired to the Motala system, the centre of which is 150 miles from Alfkarleby and 60 miles from the nearest steam station on the Alfkarleby system.

Power from Porjus (80,000 h.p.) is supplied partly for railway electrification, partly for the numerous iron-mines in the neighbourhood, and partly for electro-chemical industries. There are no very long transmission-lines in Sweden, but there are numerous systems covering a radius of fifty to seventy miles, many of which systems are arranged so that they can be linked together if desired.

A report on the hydro-electric developments of Sweden published in 1919 by the Department of Mines and Industries gives some very valuable data and costs, as it includes statistics concerning every power-station in the country. One most remarkable feature is the way in which fuel plants have kept pace with water-power plants, in spite of the fact that all the coal or oil used in the former has to be imported. Table 1 below shows the increase in power for generating electricity from 1897 to 1916.

TABLE 1.

	Horse-power from Fuel.	Horse-power from Water.
Year 1897	10,000	10,000
,, 1900	25,000	35,000
,, 1904	50,000	90,000
,, 1908	90,000	170,000
,, 1912	175,000	430,000
,, 1916	250,000	700,000

The principal uses to which water-power is put are: Iron industry, 28 per cent.; paper and pulp industry, 30 per cent.; textile industry, 5 per cent.; electro-chemical industry, 11 per cent.; power-distribution and various, 25 per cent.

The average selling-prices per unit for power, taken over the whole of Sweden, are: Power for industrial motors, 0·4d.; power for electro-chemical industry, 0·08d.; power for lighting, domestic, and farm, 2·9d.; power for electric railways and trams, 1·06d. It may be mentioned that 0·1d. per unit is equal to £2 per horse-power year at 100 per cent. load-factor.

The growth of the electro-chemical industry since its commencement in 1904 has been remarkable. In that year there were eight plants, using 9,000 kw., while in 1917 there were seventy-five plants, using 126,000 kw. and producing £3,000,000 worth of materials per year. Those included pig iron and steel, copper, zinc, ferro-silicon, calcium carbide, nitric acid, sodium sulphate, caustic soda and potash, bleaching-powder, and many others.

The summaries and figures published in this report are based on information collected from 728 electric-power stations which were operating at the end of 1916. It will be seen from Table 2 below that the vast majority of these stations were owned by private companies.

TABLE 2.

—	Number of Stations.	Horse-power installed.		
		Water.	Steam.	Oil, &c.
State power-stations	3	210,000	..	170
Municipal power-stations	28	32,391	2,454	4,610
Supply companies	166	217,679	25,357	5,586
Industrial companies	531	466,260	70,207	5,855
Total	728	926,330	98,018	16,221

In addition there is about 200,000 h.p. privately developed, driving mills direct without electrification. The percentage of power developed to that available varies considerably in different parts of the country, from 80·5 per cent. in middle Sweden down to 4·37 per cent. in north Sweden. In middle Sweden, where the percentage of development is highest, we find on the one hand a number of large stations grouped together on the big rivers, and on the other hand an extraordinary number of small- and medium-sized stations extending over practically the whole area and using practically all the available power. In this area the iron and mining industry is mainly responsible for the development, together with the timber and wood-pulp industry in the western part.

A summary of the power plants in 1917 in size-group intervals is shown in Table 3. From this it is seen that the power-stations can be divided into two main groups—a host of plants of less than 5,000 h.p., and above that isolated stations of varying size.

TABLE 3.

Size of Group (Horse-power).	Stations.		Total Output.		Percentage Output, excluding Stations over 50,000 Horse-power.
	Number.	Percentage.	Horse-power.	Percentage.	
0– 200 ..	311	39·5	36,686	3·3	4·3
200– 500 ..	200	25·4	61,049	5·6	7·3
500– 1,000 ..	107	13·6	73,768	6·7	8·9
1,000– 5,000 ..	134	17·0	285,508	25·8	33·8
5,000–10,000 ..	19	2·4	125,065	11·3	14·8
10,000–20,000 ..	6	0·8	76,710	7·0	9·2
20,000–50,000 ..	7	0·9	184,910	16·7	21·7
Above 50,000 ..	3	0·4	261,400	23·6	..
	787	100·0	1,105,096	100·0	100·0

The information contained in this table is also published for each district, from which it is seen that the extra-large stations are confined to the big industrial areas, while in the most thickly populated areas of middle and south-east Sweden there are no stations over 5,000 h.p. The small stations are equally distributed throughout the country, while the medium-sized ones of 1,000–5,000 h.p. are most numerous in the west.

Amongst the returns of 728 plants for 1916 fairly complete cost data is given of 393 stations. In order to arrive at fair average values the costs of exceptional stations have been omitted, and Table 4 shows the average costs of 239 plants, exclusive of land-purchase, water-rights, &c. All price-conversions have been made at pre-war rate of exchange—viz., £1 = 18 kroner.

TABLE 4.

Size of Stations (Horse-power).	Number of Stations.	Power installed.	Cost per Horse-power.	Canada.	
				Cost per Horse-power.	Number.
			£	£	
Less than 200 ..	65	7,066	26·7	..	..
200– 500 ..	48	15,638	17·4	18·0	16
500– 1,000 ..	45	29,104	16·2	16·5	8
1,000– 5,000 ..	61	132,086	12·8	19·3	14
5,000–10,000 ..	9	59,000	11·7	..	..
10,000–20,000 ..	4	51,300	10·7	13·7	3
Above 20,000 ..	7	305,825	8·4	14·3	8

The last two columns show similar costs for stations in Canada from records published in 1917, and are inserted for comparison.

The same figures grouped according to head show that the cheapest developments are at 100 ft.; the cost per horse-power remains practically constant down to 50 ft., and then increases more and more rapidly, until at 6 ft. it is 50 per cent. higher than at 100 ft. for powers up to 1,000 h.p., and 75 per cent. higher for plants from 1,000 h.p. to 5,000 h.p.

The costs of individual stations, of course, vary widely from this, depending on conditions at site, height of fall, provisions for extensions, &c.

The report contains a great deal of useful information which is not required for the purposes of this paper, but the next thing to do is to convert the figures and prices given therein to accord with wages and general conditions which are likely to be met with in New Zealand during the next few years. The factors for converting pre-war Swedish costs to probable New Zealand costs during the next few years are arrived at as follows :—

1. Headworks and buildings : These are approximately proportional to the average wages, which were 6s. in Sweden before the war and are now about 12s. in New Zealand. A factor of 2 is therefore used for converting these items.

2. Machinery : The probable cost of machinery in Europe during the next few years will be about double pre-war cost, and adding 50 per cent. to cover the cost of packing, freight, duty, commissions, &c., the present cost in New Zealand will be about three times pre-war Swedish costs.

Table 5 has accordingly been prepared, showing the actual detailed costs of certain Swedish plants as corrected for present Dominion conditions.

TABLE 5.

Size of Plant (Brake Horse-power).	Number of Stations.	Headworks, including Pipe-lines.	Power-stations and Buildings.	Turbines.	Electric Equipment.	Total per Horse-power.
						£
50– 200 ..	38	15·20	7·20	8·70	15·45	46·55
200– 500 ..	27	14·00	5·32	6·75	13·05	39·12
500– 1,000 ..	27	13·80	5·00	5·34	10·50	34·64
1,000– 5,000 ..	34	12·40	4·54	3·51	7·65	28·10
5,000–10,000 ..	9	13·60	2·22	3·18	6·00	25·00
10,000–20,000 ..	4	11·36	3·96	2·04	4·08	21·40
Above 20,000 ..	4	9·10	3·18	1·65	3·28	17·20

These figures are shown by the curve in fig. 1. To verify the correctness of this curve actual costs of pre-war stations in New Zealand and Tasmania, and estimated pre-war costs for Mangahao, Waikaremoana, and Arapuni, all increased by 40 per cent., have been plotted. These prices are seen to lie very close to the curve, except Lake Coleridge (partial) and Mangahao. The reason for these being high is that the headworks for the former are designed for 16,000 h.p., while regulating-dams are included in the latter. It appears, therefore, that the factors used for conversion are correct.

The next point to examine is the cost of transmission. For this purpose all the existing stations in New Zealand have been grouped according to their size, and the average length of transmission for each group has been plotted. From this the curve A (fig. 2) has been drawn, which represents the average length of transmission for various-sized schemes in New Zealand. As a check upon this the distance has been measured from the centre of distribution of the various areas enumerated in the Public Works Statement of 1920 to the nearest source of power-supply, and the distances are found to be on the average below the lengths obtained from the above curve.

Now, the cost of a transmission-line does not merely increase with the weight of copper used, but it also increases very rapidly with the voltage, on account of the increased cost of insulators, &c.; and, as the best voltage is roughly proportional to the length, it will be easily understood that the cost per mile will be greater on long lines than on short ones. The curve B, fig. 2, has been calculated on present-day costs (assuming copper costs £100 per ton), the power lost is worth £5 per horse-power year, and the rate for interest and depreciation is 10 per cent.

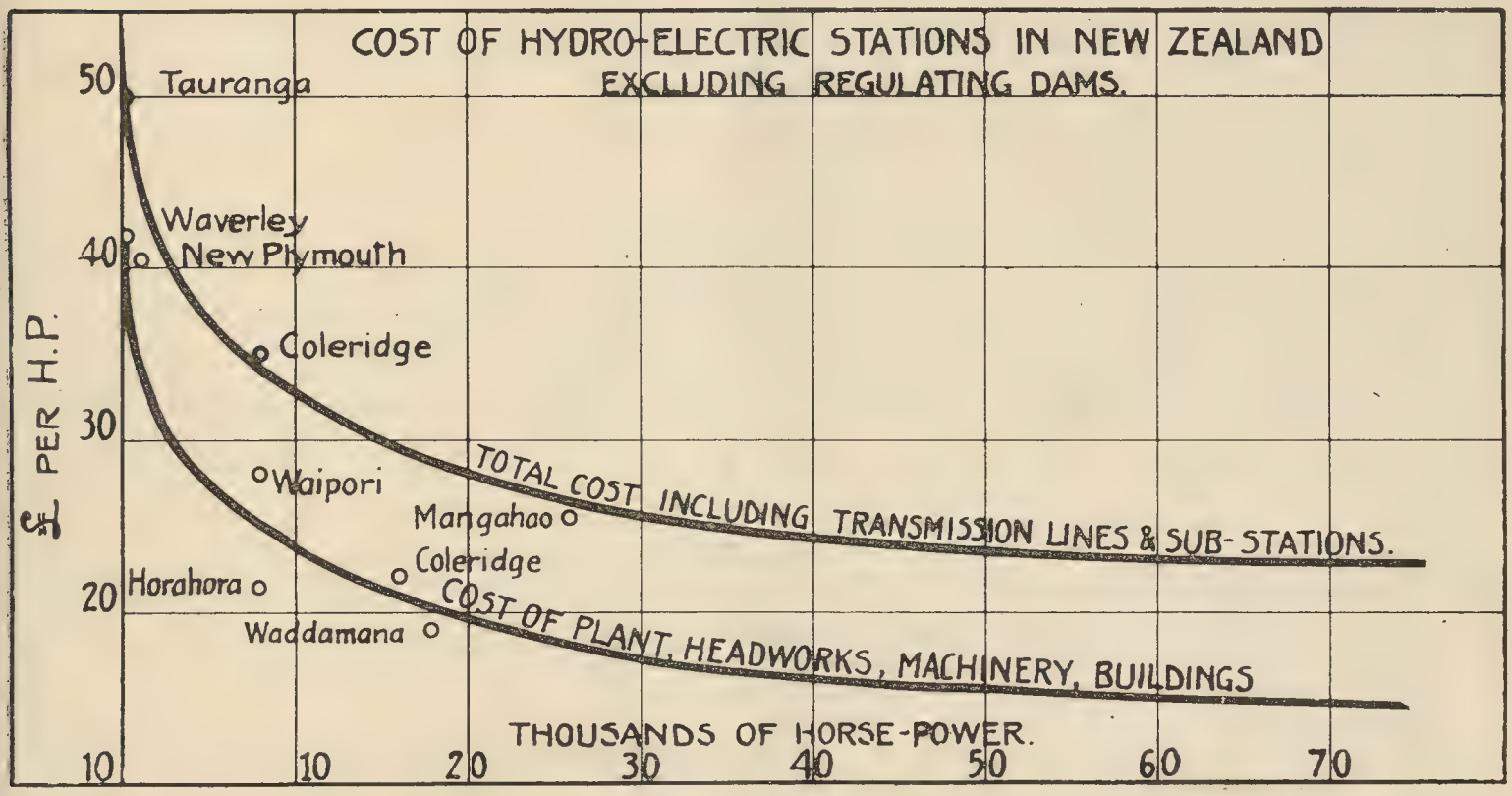


FIG. 1.

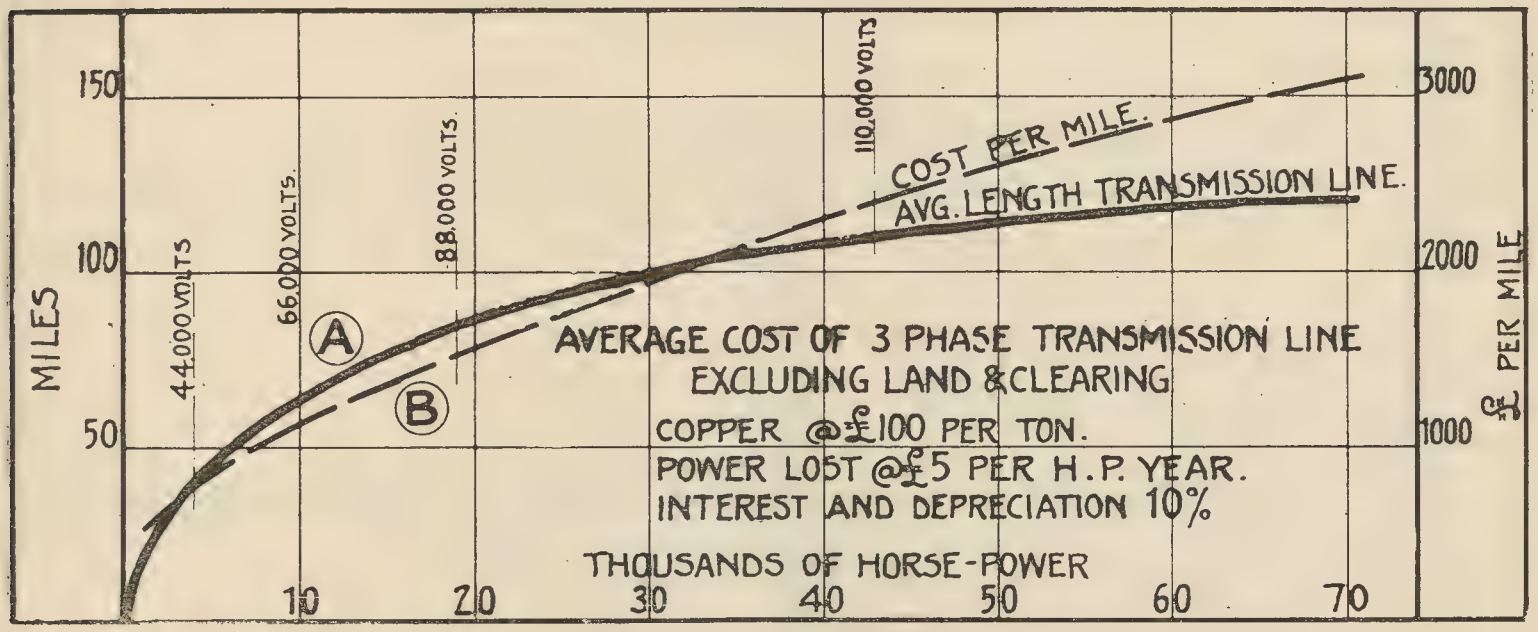


FIG. 2.

From these two sets of curves (figs. 1 and 2) we can now determine the average cost of complete hydro-electric plants of any size from the headworks down to the main substation. This has been done in Table 6, the average cost of substations having been taken from actual pre-war figures in New Zealand increased by 40 per cent. It should be noted that no allowance has been made for such items as land, water-rights, way-leaves, &c.

TABLE 6.

Average horse-power ..	125	350	750	3,000	7,500	15,000	30,000
Average transmission (miles)	2	8	14	32	50	75	100
Cost per horse-power—	£	£	£	£	£	£	£
Headworks	15·0	14·1	13·5	12·4	11·8	11·3	17·0
Turbines	8·7	7·0	5·7	3·7	3·0	2·1	
Electrical equipment ..	15·5	13·0	10·5	7·7	6·0	4·5	
Buildings, &c.	7·0	5·5	5·1	4·3	3·8	3·4	
Transmission-line ..	6·7	10·3	9·9	7·8	6·5	5·9	..
Substations	0·0	4·5	4·2	3·7	3·1	2·9	..
	52·9	54·4	48·9	39·6	34·2	30·1	..

These results are shown by the curves in fig. 1.

The next point to consider is the annual cost. This is made up of fixed or capital charges and operation and maintenance costs. The fixed charges consist of interest at 6 per cent.; depreciation at 3 per cent., which is sufficient to wipe off the whole cost in twenty years; and interest during construction, which has been based on the assumption

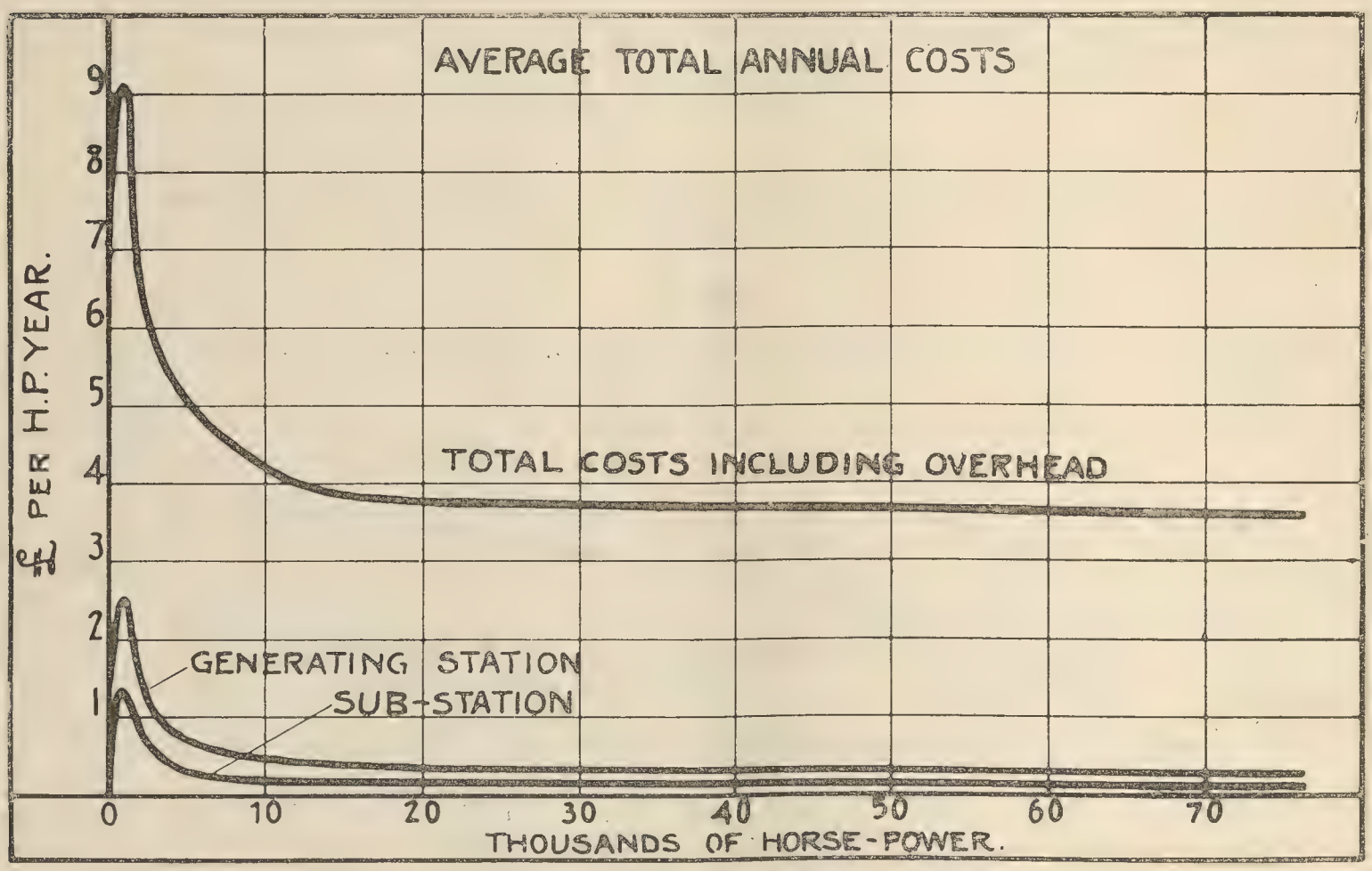


FIG. 3.

that the expenditure will be spread over the whole construction period of two years for small plants and up to three years for plants of 20,000 h.p. The other annual charges are generating costs, consisting of wages for operation and maintenance, supervision, oil, stores, &c.; transmission costs, consisting of wages for patrol and maintenance of lines, with supervision; substation costs, consisting of wages, supervision, oil, stores, &c. These annual costs are given in Table 7 below, and in the curves, fig. 3.

TABLE 7.

Average horse-power	125	350	750	3,000	7,500	15,000
Total capital cost per horse-power ..	£ 52·9	£ 54·4	£ 48·9	£ 39·6	£ 34·2	£ 30·1
Interest, at 6 per cent.	3·17	3·27	2·93	2·38	2·15	1·81
Depreciation, at 3 per cent. ..	1·58	1·63	1·46	1·19	1·07	0·90
Interest during construction ..	0·47	0·49	0·44	0·40	0·41	0·40
	5·22	5·39	4·83	3·97	3·63	3·11
Generating costs	1·65	2·00	2·55	0·90	0·53	0·37
Transmission costs	0·32	0·43	0·40	0·25	0·17	0·13
Substation costs	0·00	0·30	1·30	0·45	0·31	0·19
Total average costs	7·19	8·12	9·08	5·57	4·64	3·80

From these tables and curves it will be noticed that the capital costs of stations of 50 to 200 h.p. is less than of stations of 200 to 500 h.p. The reason for this is that the average length of transmission is very short, power is transmitted at generated voltage, and no separate substations are required.

The curves of annual costs show that the most expensive plants to run are those of 500 to 1,000 b.h.p. with an average length of transmission of fourteen miles. The reason for this is that the generating plant is so far away that a separate staff has to be maintained, with a station superintendent in charge. Stations of 200 to 500 h.p. are run with two day shifts and are unattended at night, and are under the supervision of the engineer in charge of the whole system, including distribution, so that only part of this engineer's salary is charged to generation and transmission. The smallest group of stations—50 to 200 h.p.—show a great saving in operation, as they are run entirely unattended except for a daily visit of inspection.

Having arrived in this way at average figures for the capital and annual costs of various-sized stations in New Zealand, the next thing is to consider a possible scheme for the development and supply of power over the whole of the North Island and compare it with the large central scheme proposed by the Government.

Referring to the Public Works Statement for 1920, we find that for the North Island it is proposed to supply thirty-six power districts, having a total population of about 700,000, and that it is estimated for this purpose that 160,000 h.p. will be required, or, allowing for losses, about 0·2 h.p. per head. Now, there is no doubt that ultimately this amount of power will be easily absorbed, but it is extremely doubtful whether it will find a market during the next ten years or even twenty years unless there is a phenomenal increase in the industrial work of the country. Even in Sweden, where, as already mentioned, great development has taken place and many large distribution systems exist, only 1,100,000 h.p. had been developed from water at the end of 1917 to supply a population of six millions—*i.e.*, 0·184 h.p. per head—and of this amount only 26 per cent., or about 0·05 h.p. per head, was used for general distribution, the rest being absorbed chiefly by the iron, wood-pulp, and electro-chemical industries. It therefore seems to be too much to expect that during the next ten or fifteen years it will be possible in New Zealand to dispose of more than about 0·1 h.p. per head of

population, or 70,000 h.p., especially when it is remembered that nearly 20,000 h.p. is already developed in the North Island, of which about 15,000 h.p. is used for general supply purposes.

For the sake of comparison a group of small- and medium-sized stations, having a total output of 160,000 h.p. will be considered, and alternately another group with a total output of 80,000 h.p. These groups will consist of a number of stations of various sizes similar to the groups found in Sweden, and the number of stations of each size in the groups will be made such that the total output from each size of station bears the same proportion of the whole output of the group as is found to exist in Sweden. The total cost and annual cost of the whole scheme will be found in Tables 8 and 9, from which it will be seen that in the 160,000 h.p. proposal there will be 125 stations of varying sizes, while in the 80,000 h.p. scheme there will be sixty-four.

TABLE 8.

For 160,000 h.p.

Size of Stations (Horse-power).	Average Horse-power.	Number of Stations.	Total Output (Horse-power).	Total Capital Cost.		Total Annual Cost, including Interest and Depreciation.	
				Per Horse-power.	Total.	Per Horse-power.	Total.
				£	£	£	£
50– 200	125	51	6,400	32·9	338,000	7·19	46,000
200– 500	350	32	11,200	54·4	610,000	8·12	91,000
500– 1,000	750	19	14,300	48·9	700,000	9·08	130,000
1,000– 5,000	3,000	18	51,000	39·6	2,020,000	5·57	283,000
5,000–10,000	7,500	3	22,500	34·2	768,000	4·64	104,000
10,000–20,000	15,000	1	15,000	30·1	451,000	3·80	57,000
Above 20,000	..	1	40,000	27·0	1,080,000	3·00	120,000
	..	125	160,400	..	5,967,000	..	831,000

Average capital cost per horse-power, £37·2; average annual cost per horse-power, £5·18.

TABLE 9.

For 80,000 h.p.

Size of Stations (Horse-power).	Average Horse-power.	Number of Stations.	Total Output (Horse-power).	Total Capital Cost.		Total Annual Cost, including Interest and Depreciation.	
				Per Horse-power.	Total.	Per Horse-power.	Total.
				£	£	£	£
50– 200	125	26	3,200	52·9	169,000	7·19	23,000
200– 500	350	16	5,600	54·4	305,000	8·12	45,500
500– 1,000	750	10	7,500	48·9	366,000	9·08	68,000
1,000– 5,000	3,000	9	27,000	39·6	1,070,000	5·57	150,500
5,000–10,000	7,500	2	15,000	34·2	513,000	4·64	69,500
10,000–20,000	15,000	0	..	30·1	..	3·80	..
Above 20,000	30,000	1	30,000	27·5	825,000	3·25	97,500
	..	64	88,300	..	3,248,000	..	454,000

Average capital cost per horse-power, £36·8; average annual cost per horse-power, £5·14.

It should be noted specially that the capital cost and the annual cost is practically the same per horse-power whether the full development of 160,000 is carried out or whether only half the output is developed. This is a most important point, as it shows that a partial development can be carried out just as efficiently as the full development, so that the ultimate scheme can be installed in stages in such a way that the development will keep pace with the demand for power, and no waste or loss of efficiency will occur as a result of being forced to spend large sums on the partial development in order that extensions may be made at a later date, as must necessarily be the case with the three large stations at present proposed by the Government.

In order to bring the estimated costs of this Government scheme in line with the one suggested above, the figures published in the New Zealand Year-book for 1920 have been taken and adjusted for present conditions; the cost of generating-station has been increased to 40 per cent. above pre-war, while the costs of transmission have been taken on the same basis as for smaller schemes, as per the curves in fig. 2.

To get an idea of the cost of partial development the total costs of the various stations given in the New Zealand Year-book, 1920, have been split up under various headings in the same proportion as the corresponding costs of Swedish stations. The cost of machinery has been taken as proportional to the total horse-power installed; but headworks, buildings, and foundations, &c., are more expensive for the partial development, as they have to be designed to fit in with the complete scheme. It is assumed for the partial development that Mangahao will be fully developed from the beginning, as this is only a medium-sized stream, and that Waikaremoana and Arapuni will be developed to only half their ultimate capacity of 40,000 h.p. and 96,000 h.p. respectively. Table 10 shows how the figures for the partial development are arrived at.

TABLE 10.

—	Estimated Cost per Horse-power (N.Z. Year-book, 1920).	Full Development adjusted for Present Conditions.			Partial Development adjusted for Present Conditions.		
		Brake Horse-power.	Cost per Horse-power.	Total Cost.	Brake Horse-power.	Cost per Horse-power.	Total Cost.
	£		£	£		£	£
Mangahao ..	18·30	24,000	22·80	550,000	24,000	22·80	550,000
Waikaremoana—							
Headworks ..	..	..	8·71	350,000	..	..	225,000
Turbines ..	..	..	1·62	65,000	..	..	33,000
Electrical plant ..	..	..	3·45	138,000	..	..	69,000
Buildings ..	..	..	2·62	105,000	..	..	80,000
Totals ..	13·16	40,000	16·40	658,000	20,000	20·35	407,000
Arapuni—							
Headworks ..	..	..	7·15	685,000	..	..	535,000
Turbines ..	..	..	1·35	130,000	..	..	61,000
Electrical plant ..	..	..	2·85	273,000	..	..	130,000
Buildings ..	..	..	2·15	207,000	..	..	150,000
Totals ..	10·80	96,000	13·50	1,295,000	45,000	19·45	876,000
Grand totals ..	..	160,000	15·67	2,503,000	89,000	20·61	1,833,000

These costs are for the generating-stations only, reckoned at an advance of 40 per cent. on pre-war values, as against the 12 per cent. advance allowed for in the 1920 Year-book. The estimated capital and annual costs of the whole scheme are given in Table 11.

TABLE 11.

Capital and Annual Cost of Central Scheme.

—	160,000 h.p.	160,000 h.p.	80,000 h.p.
	N.Z. Year-book, 1920: Pre-war plus 12 per Cent.	Present Estimate: Pre-war plus 40 per Cent.	Present Estimate: Pre-war plus 40 per Cent.
	£	£	£
Capital cost of generating-stations	2,061,723	2,503,000	1,650,000
Main transmission-lines, 1,120 miles at £1,750 ..	1,553,880	1,960,000	..
Main transmission-lines, 700 miles at £1,750 ..	..	..	1,230,000
Branch transmission-lines, 310 miles at £1,000 ..	241,360	300,000	300,000
Main substations, at £3 per horse-power ..	838,808	480,000	240,000
Secondary stations, at £4 per horse-power ..		640,000	320,000
Distribution-lines and substations	2,086,000	..	..
	6,781,771	5,883,000	3,740,000

Annual Cost.

—	160,000 h.p.	80,000 h.p.
	Present Estimate: Pre-war plus 40 per Cent.	Present Estimate: Pre-war plus 40 per Cent.
	£	£
Interest on capital at 6 per cent.	353,000	224,000
Depreciation at 3 per cent.	176,500	112,000
9 per cent. on interest during construction (four years)	79,500	50,000
	609,000	386,000
Generating costs at £0·275 and £0·3 per horse-power respectively	44,000	24,000
Transmission costs, main lines, at £30 per mile ..	33,600	21,000
Transmission costs, branch lines, at £22 per mile ..	6,700	6,700
Substation operation at £0·4 and £0·5 per horse-power respectively	64,000	40,000
Total annual cost	£757,300	£477,700
Total annual cost per horse-power ..	£4·74	£5·98

Having arrived at these costs, the next thing is to compare them with the costs of the alternative group scheme :—

	Central Scheme.	Group Scheme.
	£	£
160,000 h.p.—		
Total capital cost per horse-power	36·80	37·20
Total annual cost per horse-power	4·74	5·18
80,000 h.p.—		
Total capital cost per horse-power	46·80	36·80
Total annual cost per horse-power	5·98	5·14

From these figures it will be seen that under the group scheme the capital expenditure per horse-power is practically independent of the size of the scheme, and is the same as the ultimate expenditure per horse-power on the Government or central scheme, but the annual cost of the group scheme is rather greater than the annual cost on the ultimate central scheme, so that if it is possible to find a market for 160,000 h.p. there is no doubt that the central scheme is the cheapest. On the other hand, the annual cost of the group scheme for an 80,000 h.p. development is considerably less than that of the central scheme for the same development.

Apart from the question of cost is that of reliability, and there can be little doubt that the group scheme is far better in this respect. In the first place, most of the transmission is carried out at medium voltages, which reduces the insulator and leakage troubles very considerably; and, in the second place, a failure on one line will affect only a comparatively small area, while in the central scheme it might, and probably would, disorganize the whole electric supply over a very large district.

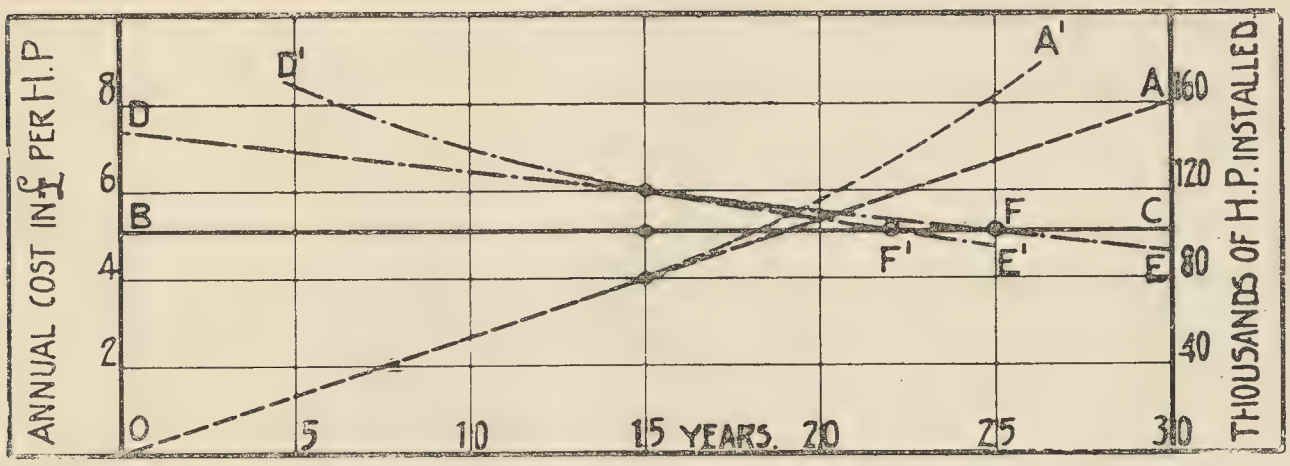


FIG. 4.

As far as cost is concerned, then, it will be seen that the relative merit of the two schemes is entirely dependent on the rate of growth of the demand for power. At present there is about 40,000 h.p. in use in the North Island, half of which is developed from water, and it seems reasonable to suppose that the demand will not increase by more than 80,000 h.p. during the next fifteen years, even when replacements to steam plant are considered.

In fig. 4 the line OA represents the assumed rate of growth in the demand for power, while the curves BC and DE represent the annual cost per horse-power for operating under the group scheme and the Government scheme respectively. The curve BC is practically a horizontal straight line, as the cost per horse-power is independent of the amount of power developed. The curve DE has been drawn as a straight line through the points obtained for the 80,000 h.p. and 160,000 h.p. schemes, assuming that the demand grows by 80,000 h.p. in the first fifteen years and by another 80,000 h.p. in the next fifteen years. Actually this curve would be somewhat as shown by the dotted line D^1E, while in all probability the increase would be more rapid during the second fifteen years than during the first, as indicated by the dotted line OA^1. The effect of this would be to bring the point E back towards the twenty-

five-year line, as at E^1, so that the curves would cross at F^1 after about twenty-two years, instead of twenty-six years as at F.

These curves indicate that in New Zealand it will be much cheaper to start with the group system of development until the demand has grown to about 150,000 h.p. in the North Island, and then to change over and go in for the big schemes proposed by the Government. The curves also indicate that this will probably occur in about twenty to twenty-five years' time; and, as depreciation fund of 3 per cent. allows for the complete replacement of the plant after twenty years, this will exactly fit in, so that the group system will then be scrapped after having built up a market for the large schemes, ensuring their success, and having supplied cheap power throughout the country during the process.

In conclusion, I should like to point out once more that the figures I have worked on are average figures, and therefore must not be taken to represent the cost of any individual plant, for it is found from actual results that the capital costs per horse-power varied very greatly and were as much as 50 per cent. above or below the average values.

I wish also to repeat that the objects of this paper are—(1) to promote discussion on an important subject; (2) to point out that the scheme outlined by Mr. Parry was a scheme to be kept in view, but not necessarily to be embarked upon immediately; (3) to indicate that owing to the smallness of the population and the absence of large industrial areas in New Zealand it would be wise to go carefully and not be too ambitious in our hydro-electric developments; and, finally, to show that by a process of group or step-by-step development we can not only make the whole scheme pay its way from the start, but can actually produce power more cheaply during the first fifteen or twenty years, until such time as there is sufficient demand for power to load up the big stations to somewhere near their full capacity.

THE VENATION OF THE GENUS MNESARCHAEA (LEPIDOPTERA),

With a Description of a New Species.

By ALFRED PHILPOTT, F.E.S., Cawthron Institute, Nelson.

THE genus *Mnesarchaea* Meyr., as far as is yet known, occurs only in New Zealand. As, however, the species are all small and inconspicuous insects, and generally make only short flights near the ground, it is highly probable that other forms remain to be found; it is also quite possible that the genus may yet be recorded from Australia.

The object of the present article is to give an exact account of the venation of the genus, the writer having had ample material at his disposal for the examination of all the species. The description of a new species is also included.

Mnesarchaea contains four species, as under :—

M. paracosma Meyr. (*Trans. N.Z. Inst.*, vol. 18, p. 180).
M. loxoscia Meyr. (*Trans. N.Z. Inst.*, vol. 20, p. 90).
M. hamadelpha Meyr. (*Trans. N.Z. Inst.*, vol. 20, p. 91).
M. fusca n. sp. (this volume, p. 82).

The genus is defined, with reference to the neuration, by Meyrick (*Genera Insectorum*, fasc. 132, p. 3) as "Forewings with 1*b* [2A] simple, 2 [Cu_{1b}] from angle, 6 [M_1] out of 8 [R_4] or separate, 7 [R_5] and 8 stalked, 7 to termen, 9 [R_3] and 10 [R_2] from posterior third of cell, 11 [R_1] absent. Hindwings, neuration as in forewings but 6 always separate."

The systematic position of the genus seems to be that of a very highly specialized offshoot from the typical Micropterygids ; Meyrick (as above) places it in a subfamily by itself, the Mnesarchaeinae, and considers that it occupies an intermediate position between the Micropterygidae and the Plutellidae and Tineidae, though not on the direct line of descent. Tillyard (*Proc. Linn. Soc. N.S.W.*, vol. 44. p. 134) raises this subfamily to family rank.

I now give a detailed description of the venation of the genus, followed by a comparison with that of *Sabatinca* Wlk., the only other jugo-frenate genus in New Zealand.

Forewing.

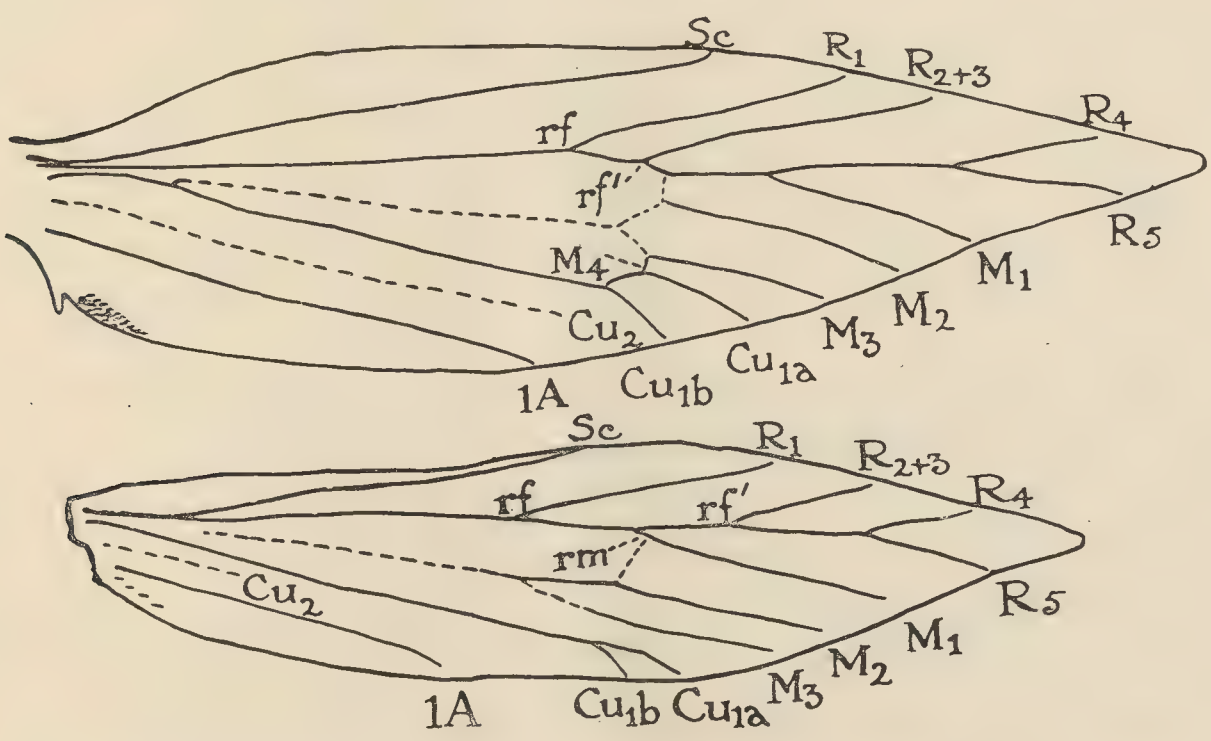
Subcosta an unbranched vein, free of the radius except at base.

Radius four-branched ; *rf* situated far distad, at about $\frac{4}{5}$ of cell. R_{2+3} missing ; *rf'* at apex of cell. Areole absent.

Media : The stem of M is traceable through the cell and joins the first cubitus near the base. In two of the species, *M. hamadelpha* and *M. fusca*, M_1 anastomoses with the stalk of R_{4+5} thus dispensing with the cross-vein *r-m* ; in the remaining two forms M_1 is connected with R_{4+5} by *r-m*. M_2 and M_3 fork back shortly into the cell.

Cubitus : The first cubitus forks, in a normal position, into Cu_{1a} and Cu_{1b}, the upper branch being joined by a short and weak M_4. Cu_2 is a very weak vein, and appears to be far on the way to being lost altogether.

Analis : 1A is a well-marked vein, but 2A and 3A are not present.



Wings of *Mnesarchaea hamadelpha* Meyr. 1A, first analis ; Cu_{1a}, Cu_{1b}, branches of the first cubitus ; Cu_2, second cubitus ; M_1, M_2, M_3, M_4, branches of the media ; R_1, upper primary branch of the radius, the lower being the radial sector ; R_{2+3}, R_4, R_5, branches of the radial sector ; *rf*, the primary radial fork ; *rf'*, the secondary radial fork ; *r-m*, the radio-median cross-vein.

Hindwing.

The hindwing agrees with the forewing except in the following particulars: M_1 is always separate; the forking of M_2 and M_3 is farther basad; and M_4 is absent.

Comparison of the Venation of Sabatinca *and* Mnesarchaea.

	Sabatinca.	*Mnesarchaea.*
hm and Sc_1 ..	Present	Absent.
sc-r	Frequently present ..	Absent.
R_1	Strongly forked	Unbranched.
R_2 to R_5	The four branches present ..	R_{2+3} absent.
Areole	Always present	Never present.
M_1	Always separate	Sometimes out of stalk of R_{4+5}.
mf	Far basad from apex of cell ..	Close to apex of cell (in the hindwing the position is practically as in *Sabatinca*).
Cubito-median Y-vein	Present	Absent.
cu-a$_1$ and *ia*$_1$ ..	Frequently present ..	Absent.
Anal veins	All present	2A and 3A absent.

Hindwing.—In the hindwing the differences are, for the most part, as in the forewing, but the following exceptions may be noted: In *Sabatinca* R_1 always runs into the lower branch of Sc, the greater part of its basal portion usually becoming obsolete; in *Mnesarchaea* R_1 is always a free vein. In *Sabatinca* 1A is basally coincident with Cu_2, leaving that vein at about $\frac{1}{3}$ and obliquely joining 2A; in *Mnesarchaea* there is no trace of this arrangement, Cu_2 being almost obsolete and 1A (or 2A) being free throughout.

It will be seen at once from the above that all the venational modifications in *Mnesarchaea*, as compared with *Sabatinca*, tend towards greater specialization.

DESCRIPTION OF A NEW SPECIES OF MNESARCHAEA.

Mnesarchaea fusca n. sp.

♂ ♀. $7\frac{1}{2}$–$8\frac{1}{2}$ mm. Head whitish-yellow. Palpi and antennae yellow. Thorax fuscous, laterally yellowish. Abdomen fuscous mixed with yellow. Legs whitish-yellow, tarsi fuscous, apically ringed with yellow. Forewings, costa evenly arched, apex pointed, termen rounded, extremely oblique; dark fuscous with violet-purplish iridescence; many scattered yellow scales, tending to form an outwardly-oblique fascia from costa before middle extending to disc, and a spot, directed inwardly, on costa at $\frac{5}{6}$; cilia fuscous, suffusedly barred with yellowish-white. Hindwings and cilia fuscous, purplish-tinged.

Resembling *M. paracosma* Meyr., but with a much less pointed apex of forewing and considerable differences in the markings.

Gouland Downs, early in February. Six specimens found by sweeping low herbage in the forest. One example also taken later in the month on the Dun Mountain at 3,000 ft.

Holotype (♂), allotype (♀), and paratypes in coll. Cawthron Institute.

Since the above was written I have learned from Mr. G. V. Hudson, of Wellington, that he was fortunate enough to secure a long series of the new species at Wilton's Bush on the 7th and 9th March last. Mr. Hudson's specimens were taken by sweeping ferns in damp places in the forest gullies.

ASCOSPORE EJECTION OF THE APPLE AND PEAR BLACK-SPOT FUNGI.

Characteristics noted during the Season 1921.

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DURING the spring and early summer of the present season a series of experiments was carried out by the writer with the object of determining the duration and noting any characteristic feature of the period of discharge of ascospores from the perithecia of *Venturia inaequalis* and *V. pirina*, the fungi responsible for the black spot of apple and pear respectively. Large numbers of the flask-shaped perithecia are to be found in spring in the majority of the dead leaves of any infected tree, whether the leaves lie exposed on the surface of the soil or are buried beneath it. Since the number of perithecia whose ostioles when mature project through the lower surface of the leaf is so very great, the few whose ostioles project through the upper have been regarded as negligible in the present experiments, those of the lower surface only being considered. The technique involved is extremely simple, being based on the forcible ejection of the ascospore from the mature perithecium. When a smooth object with a plane surface is placed parallel to and at a suitable distance from the surface of a leaf that bears perithecia, the ascospores on being discharged, owing to a slight stickiness of their walls, adhere to the object on striking it. As the natural adhesiveness of the ascospores, however, may not withstand the persistent action of rain, resort is usually made to the use of an artificial adhesive. In the present instance ordinary slides were used to arrest the ascospores, and the adhesive used, which was spread in a thin film on the lower surface of the slide, consisted either of glycerin jelly or of egg-albumen + glycerin. These two substances were equally effective in retaining the spores, but, on the whole, egg-albumen + glycerin is to be preferred, as it gives a more uniform film on the slide, and proves more serviceable when there is a likelihood of time elapsing between the securing of the spores and the examination of the slide; for when it is the medium used shrinkage of the spores, which prevents their being readily counted, does not usually occur even after an interval of several weeks, and interruptions in the examination of the slides can therefore be made with security.

It is usually considered in experiments of the present type that a sufficiently accurate indication of the number of spores on a slide has been secured when those present in an arbitrarily chosen number of fields of view have been determined, the magnitude of the field of view and the number of fields counted per slide being, of course, the same for every slide. It seems, however, that the haphazard choice of, for instance, twenty-five fields of view per slide might on occasion yield results which, if the discharge were taking place irregularly within small areas, as has frequently been found to occur, could not be regarded as accurately representative of the discharge from the whole leaf. In order, therefore, that in the present instance a more typical and complete record should be secured, an area of moderate but adequate size was completely and minutely examined. The slides used were 3 in. in length and 1 in. in breadth, and

across them at 1 in. from either end were drawn two parallel lines, thus delimiting the central inch of the slide. The whole of this central inch was examined by the aid of a mechanical stage and all the spores within it counted. By this means not only were many more fields examined per slide than has usually been done, but the danger of the accidental examination of an undue proportion of either densely crowded or sparsely sprinkled fields was largely obviated.

In the accompanying tables (pp. 89, 90), the number of ascospores discharged from five apple-leaves and three pear-leaves during the months September to December is set forth, and in addition the last table contains the figures obtained from a second experiment involving four apple-leaves which was set up on December 6. The sets—two of apple-leaves and one of pear—thereafter continued to be examined daily until December 20, when all three were brought to a close. Across the top of the table for each month is the record (in points) of the daily rainfall in Nelson, which was taken at 9 a.m. each day, and refers to the rainfall during the preceding twenty-four hours. The record of the spore discharge each day refers to the same period of time. The leaves of the experiment were kept as nearly as possible under normal conditions, being placed so that they were sheltered during part of the day by the shade cast by a hedge, but were always freely exposed to the rain. The apple-leaves of the first experiment are lettered A_1 to A_5, the pear-leaves P_1, P_2, P_3, and the apple-leaves of the second experiment A_1 to A_4.

The record of the discharge from the perithecia of the apple-leaves will be considered before that from those of the pear. The apple-leaves of the first experiment were set up on September 14. Rain fell on this day and, with one exception, on every day from September 16 to September 22. As will be seen from the table for September, with this wet period begins the record of the season's discharge of ascospores. As might be expected, at such an early stage in the season of spore ejection the discharge was irregular and relatively small. In the case of a few leaves not included in the experiment a slight discharge occurred during September 14–15, and, strictly speaking, the rain of September 14 should probably be regarded as responsible for the initial discharge of ascospores for the season 1921. The immaturity of the majority of the perithecia examined on September 14, together with the inhibitory period of fourteen dry days that immediately preceded this day, precludes the possibility of the occurrence of a general discharge prior to September 14.* Probably there is but little doubt that this period, September 14–22, is that of the first general discharge of the season for this district at least, and possibly for the apple-growing districts of New Zealand as a whole.

During the five dry days that intervened between this period and September 28 large numbers of perithecia in four of the total five leaves were evidently closely approaching maturity; for with the 3 points of rain on September 28 a distinctly heavier and more uniform discharge of spores took place. From two leaves this discharge did not stop with the cessation of rain, but, as frequently happens, continued less vigorously during at least a portion of the succeeding twenty-four hours.

During the next interval, which comprised the three rainless days between September 28 and October 2, the vast majority of the perithecia came to maturity, and in response to the rain which began on October 2 and continued, with intervals, each day until October 11 there resulted

* This question is more fully discussed in the *New Zealand Journal of Agriculture*, October, 1921, p. 217.

the exceptionally frequent ejection of spores characterizing this, the period of maximum discharge for the season.

The figures so far recorded for the two months give a clear indication of the inhibitory action that one of the two regulatory factors governing spore discharge may exert upon it independently of the second factor. These two factors comprise—first, the maturity of the perithecia, which includes the maturity of the majority of the contained asci and spores; and, secondly, the presence of sufficient moisture, on the absorption of which the rupture of the asci, with its accompanying ejection of spores, is alone able to take place. If now the tables be examined with a view to noting the independent action of these two factors it will be seen that during the initial period of discharge in mid-September there was much rain, but as only a few perithecia were mature the discharge was relatively small. On September 28 a moderate amount of rain fell, but a greater number of perithecia were then mature, and the discharge was therefore greater than in the preceding period. On October 2 and 3, on the other hand, there was comparatively little rain, though what there was was evidently sufficient for the purpose of spore ejection; but such large numbers of perithecia were mature by this time that during these and the next five days there occurred the extremely heavy discharge indicated by the figures of the table.

After the passing of this wave of maximum perithecial development each succeeding wave of development will be seen to bear fewer discharging perithecia. By October 24 two of the five leaves have ceased to yield spores, and the response of the perithecia of the other three leaves, with the exception of the tardily active A_5, becomes more erratic and weaker as the end of November approaches. But even the late activity of A_5, called forth by the prolonged rain during the last week of November, did not survive the last small discharge on December 6. Records were taken until December 20, but with the final discharge of A_5 on December 6 the period of ascospore ejection for the season 1921 may be considered to close so far as apple-leaves are concerned.

The discharge of the ascospores from the leaves of the pear will now be considered. Owing to the fact that the writer did not succeed in obtaining pear-leaves with mature perithecia until September 24, an interval of ten days elapsed between the setting-up of the apple-leaves and that of the pear. As a result no record for the latter was obtained corresponding to that of the first apple discharge of September 16–22. Three rainless days succeeded the day on which the experiment was begun, and in consequence the first recorded discharge from the pear-leaves did not occur until September 28 (when the second discharge from the apple-leaves was taking place). Nevertheless, as a few ruptured perithecia were noticed in the pear-leaves on September 24 as they were being examined prior to being set up, it was evident that the primary discharge from at least a small proportion of the perithecia had already taken place. Moreover, since the number in which the discharge had occurred was small, the date of its occurrence was judged to be not far distant, lying probably within the period September 14–22. In spite, therefore, of the absence of an accredited record it is deduced that the primary discharges for the season from both pear and apple leaves coincided in occurring within the period September 14–22.

The small number of spores ejected from the pear-leaves on September 28 is somewhat surprising when the enormous number of perithecia which must have been practically mature at that date is considered; for that many were then almost ready to discharge their spores is evident from

the great output that occurred during the shortly succeeding wet period beginning on October 2, which proved in the case of the fungus in the pear-leaf, even more markedly than in that of the apple-leaf, to be the period of maximum spore ejection for the season.

As will be seen from the records of especially this and the two succeeding wet periods (October 2–11, October 14–17, October 20–23), the output of spores from pear perithecia (as compared with that of spores from apple perithecia) is characterized by the greater total number of spores ejected, by a more uniform daily ejection, and by more prolonged periods of ejection. These characteristics are maintained in the discharges throughout October and November; but during December, by which time the ejection from apple and pear leaves alike has become both small and erratic, the specific characteristics of the two fungi, as might be expected, are no longer evident, although greater persistence of discharge from the pear perithecia is even now noticeable.

What had seemed from the record of the apple-leaf A_5 during November 21–28 to be an exceptional case of belated ejection is evidently not of rare occurrence, for the behaviour of the perithecia in the apple-leaf finds a close parallel in that of the perithecia of the third pear-leaf during the same period, and the two can therefore but be regarded as somewhat unusual but not wholly abnormal cases of prolonged activity.

Discharge from the pear perithecia ceased on December 12—a few days later than from those of the apple. After this date leaves both of apple and of pear, whether those of the experiment or others taken directly from the ground of the orchard, revealed only ruptured perithecia together with, occasionally, a few odd perithecia whose contents, though still undischarged, were dry and shrivelled and incapable of further development.

Thus in both apple and pear leaves the discharge of ascospores during the spring and summer of 1921 took place at intervals during the three months mid-September to mid-December; for all eight leaves of the experiment the maximum total spore-output of any one wet period occurred during that of October 2 to October 11—*i.e.*, distinctly early in the season's discharge; and, finally, in the case of the majority of the leaves the maximum average daily output of any period and the maximum single day's output also occurred during this period.

Climatic conditions prior to and during the early stages of perithecial development probably exert a greater and more lasting influence upon the subsequent development of the perithecia than do those to which the latter are subjected during the later phases of their development; for, although the presence or absence of rain regulates the discharge of spores when the perithecia are mature, it is the climatic conditions (together with that most imperfectly comprehended factor, the constitution of the fungus) which, by initiating and subsequently furthering or retarding the early development of the perithecia, determines the major question of when they shall mature —whether uniformly early or uniformly late in the season. In view, therefore, of the possible range of perithecial development, the maturing this season of unusually large numbers early in the season and immediately prior to the period of heaviest rainfall may have been an unusual coincidence, and the consequent falling of the discharge into one early period of maximum discharge and five subsidiary periods may not be the typical manner of discharge for the average year. Its occurrence this season, however, is sufficient argument in favour of the possibility of its recurrence in future years to justify stressing the importance of taking adequate precautions against infection early in the season. Whether these precautions shall consist of removing the source from which the ascospores will be

ejected, or of covering the tree with a film of fungicide so that when the ascospores are borne on to it they will be unable to germinate, or whether both these forms of precaution shall be undertaken, lies within the decision of the orchardist. But in view of the magnitude of the early periods of discharge it is essential that such precautionary measures as are taken should be begun preferably at the beginning of September, and certainly well before October.

Broadly speaking, the period of danger of ascospore infection may be said to close with the end of October, for by that time only a few perithecia are discharging their spores, and danger is to be apprehended rather from the conidia which will already have been developed on the living leaves and young fruit as the result of infection during the preceding month and a half by previously ejected ascospores than from the few ascospores that are still being discharged from the dead leaves of last year.

In addition to the preceding experiment, a smaller one, in which four apple-leaves were used, was set up on similar lines in the hope of determining whether, when for any reason perithecia are prevented from discharging their ascospores at the normal time, they retain their power of spore ejection, and, if so, for how long. The leaves used in this experiment were gathered with those set up on September 14, but were kept without water from that day until December 6, on which day the experiment in which they were to be tested was begun. On December 8 and 9 their first spore ejection took place, and during these two days the discharge from three of the four leaves, as will be seen on comparing the small final table (apple-leaves, second series) with that recording the discharge for the previous series, was distinctly heavier than any that had taken place from leaves under normal treatment during the preceding month or even more. This first discharge was the only one of practical significance that the apple-leaves in question underwent, for on the 12th appreciable numbers were ejected from one leaf only, and by December 15 ejection had ceased in the case of all four. From this small experiment it is concluded that when normal spore discharge is accidentally prevented the perithecia retain their power of ejecting spores in fairly large numbers for a month to a month and a half after the major ejections may be expected to have ceased in leaves exposed to normal conditions. In the present instance the drought was excessive, for it lasted nearly three months. Moreover, within that time the majority of the perithecia passed through one of the most sensitive phases of their development—that during which the ascospores are being delimited within the asci. Had, therefore, the drought—or other inhibitory condition—been of shorter duration, or had the stages of development through which the fungus passed included less critical phases, the ejection of ascospores at the first discharge after the resumption of normal conditions would probably have been greater, and the series of discharges more prolonged, than was the case under the conditions of the experiment.

To the orchardist, therefore, who ploughs the leaves under the soil, keeps them there temporarily, but later runs the risk of bringing them to the surface by further cultivation, no guarantee can be offered that the leaves so treated will not bear numbers of healthy perithecia ready to discharge their spores on the first suitable occasion. In the first place, it is much to be doubted whether any depth of ploughing would be sufficient to ensure such irregularity in the air and water supplies as would materially arrest the development of the perithecia; and, in the second place, it is rather to be feared that such leaves as are buried just beneath the surface are being subjected to conditions not harmful to, but ideal for, the develop-

ment of the fungus ; for when they are so situated they are largely protected from the danger of desiccation, and—what is of greater importance—the fine tilth of the well-kept orchard ensures that they shall have a constant supply of moisture. In fact, so suitable is such a position that if leaves lying upon and just beneath the surface of the soil be examined it will usually be found that the perithecia of those from beneath the surface are slightly more advanced in their state of development than are those which have been exposed.

If the leaves are kept permanently buried, whether deeply or near the surface, the ascospores on being discharged will impinge on the particles of soil and there (if the common belief that at this stage the mode of life of the fungus is wholly parasitic be correct) die for want of a host plant. If, on the other hand, leaves, either from the questionably suitable position in which deep ploughing places them or from the distinctly favourable position which merely turning them under the surface ensures, be brought to the surface within, say, six to eight weeks after the maturation of the perithecia, there is nothing to prevent their being an immediate source of danger as soon as rain occurs. Whether, therefore, the ploughing-in of the leaves shall be a reliable method of averting the danger of ascospore infection or not depends solely on the condition of their not being brought to the surface of the soil by subsequent cultivation.

SUMMARY.

1. In *Venturia inaequalis* and *V. pirina*, in apple and pear leaves respectively, ascospore ejection for the season 1921 began probably on September 14, reached its maximum on and immediately after October 2, ceased to be of practical significance by October 31, and ceased completely by December 12.

2. The season's discharge from both pear and apple leaves fell into one period of maximum discharge which occurred early in the season, five subsidiary periods of practical significance, and several negligibly small periods.

3. The maximum total output of spores for any one wet period occurred in the case of every leaf, pear and apple alike, during October 2 to October 11.

4. For the majority of the leaves the maximum average daily output for any wet period and the maximum single day's output for the season also occurred during the period October 2 to October 11.

5. The output of spores from pear-leaves, as compared with that from apple, is characterized by—(1) A greater total number of spores ejected during the season ; (2) a more uniform daily ejection ; (3) more prolonged periods of ejection.

6. A complete drought of nearly three months' duration, during which time the majority of the perithecia passed through a relatively sensitive phase of development, did not prevent an appreciable ejection of spores from taking place when the drought was broken, although in normal leaves by that time ejections of magnitude had ceased for a month to a month and a half.

7. From 6 it is deduced that the ploughing-in of leaves can be effective in preventing ascospore infection only if the leaves are permanently retained beneath the surface of the soil.

8. Since the usual system of cultivation followed in the orchard tends to bring at least a certain proportion of the leaves to the surface after they have been ploughed in, it is wiser that this danger should be avoided by destroying the leaves, preferably by fire, as soon as they have fallen from the tree in autumn.

Apple and Pear Leaves, First Series.

Record of the Number of Ascospores discharged from 1 Square Inch of Leaf-surface from September 14 to December 20.

Rainfall recorded in points (100 points = 1 inch).

Sept. ..	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Rainfall	..	..	..	..	..	..	..	..	..	..	..	..	..	5	..	135	274	12	32	15	..	3	..	..	..	..	..	3	..	..
A_1 ..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	28	81	30	73	..	3	..	..	..	10	..	203	..	..
A_2 ..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	14	8	..	281	126	..	100	..	..	..	1	..	398	51	..
A_3 ..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	11	40	9	..	1	..	..	..	..	..	503	139	..
A_4 ..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	5	4	9	..	..	14	..	..	..	..	..	27	..	..
A_5 ..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	3	1	10	52	16	..	8	..	..	..	1	..	725	..	..
P_1 ..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	9	..	..
P_2 ..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	8	..	..
P_3 ..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	57	..	..

Oct. ..	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Rainfall	..	3	2	..	79	51	56	22	..	63	84	..	..	4	7	208	39	..	..	89	67	..	143	..	..	..	..	..	..	..	..
A_1 ..	..	1569	1201	98	145	16	3	..	..	17	5	..	..	60	11	161	8	..	..	10	..	..	7	..	..	..	..	..	..	..	..
A_2 ..	..	508	703	10	415	35	107	22	..	12	59	..	..	..	12	76	18	..	..	81	45	..	..	..	..	..	..	..	..	..	..
A_3 ..	..	2141	837	21	189	576	41	4	..	71	108	..	..	..	5	153	..	..	..	32	10	..	1	..	..	..	..	..	..	..	..
A_4 ..	..	25	19	..	21	19	36	7	..	8	73	..	..	4	14	109	..	..	..	..	..	..	19	..	..	..	..	..	..	..	..
A_5 ..	..	937	1030	233	495	1102	512	31	7	37	304	16	..	6	162	20	8	..	..	..	..	..	1	..	..	..	..	..	..	..	..
P_1 ..	..	753	218	321	817	1055	1621	898	75	838	915	38	..	329	81	189	742	128	..	101	123	..	2570	119	..	..	..	..	..	..	..
P_2 ..	..	1204	2118	428	563	2010	3917	1970	103	308	25	..	..	182	61	982	317	733	6	590	110	31	447	..	..	..	..	..	..	..	..
P_3 ..	..	1801	927	63	4876	1921	1368	614	201	489	715	85	..	..	88	1951	1009	801	2	..	..	..	556	284	..	..	..	..	..	..	..

APPLE AND PEAR LEAVES, FIRST SERIES—*continued.*

Nov. ..	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Rainfall	..	..	..	..	..	15	..	..	4	..	..	..	..	..	..	1	..	..	..	..	12	27	26	3	18	6	..	5	..	..	
A_1 ..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	
A_2 ..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	
A_3 ..	..	..	..	..	..	7	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	5	..	..	..	..	..	..	..	..	
A_4 ..	..	..	..	..	..	..	..	..	2	..	..	..	..	..	..	..	..	..	..	..	..	17	..	..	..	..	..	..	..	..	
A_5 ..	..	..	..	..	..	5	..	..	4	..	..	..	..	..	..	55	..	..	..	..	7	244	121	88	..	14	..	17	..	..	
P_1 ..	..	..	..	..	..	318	147	..	15	..	..	..	..	..	..	11	..	..	..	..	82	37	..	..	..	..	..	..	..	..	
P_2 ..	..	..	..	..	..	121	13	..	49	..	..	..	..	..	..	10	..	..	..	..	6	..	..	..	..	..	..	..	..	..	
P_3 ..	..	..	..	..	..	159	5	..	27	8	..	..	..	..	..	1	..	..	..	..	29	181	96	78	13	2	..	7	..	..	

Dec. ..	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Rainfall	..	..	..	..	1	111	..	3	1	..	..	74	..	..	4	..	..	..	..	..	..	..	..	..	77	6	..	3	..	35	8
A_1 ..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..											
A_2 ..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..											
A_3 ..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..											
A_4 ..	..	..	..	..	19	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..											
A_5 ..	..	..	..	..	17	4	..	..	..	..	..	..	..	..	..	..	..	..	..	..											
P_1 ..	..	..	..	..	..	..	..	3	..	..	..	70	..	..	..	..	..	..	..	..											
P_2 ..	..	..	..	..	..	..	..	5	..	..	..	..	..	..	..	..	..	..	..	..											
P_3 ..	..	..	..	..	12	13	..	..	..	..	..	..	..	..	..	..	..	..	..	..											

APPLE LEAVES, SECOND SERIES.

Record of the Number of Ascospores discharged from 1 Square Inch of Leaf-surface after a Drought of Three Months.

Dec. ..	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Rainfall	..	..	..	..	1	111	..	3	1	..	..	74	..	..	4	..	..	..	..	..	..	..	..	..	77	6	..	3	..	35	8
A_1 ..	..	..	..	..	..	..	..	1978	106	..	..	..	..	..	..	..	..	..	..	..											
A_2 ..	..	..	..	..	..	..	..	319	98	..	..	..	..	..	..	..	..	..	..	..											
A_3 ..	..	..	..	..	..	..	..	19	..	..	..	1	..	..	..	..	..	..	..	..											
A_4 ..	..	..	..	..	..	..	..	831	357	..	..	24	..	..	..	..	..	..	..	..											

FURTHER NOTES ON THE EDIBLE FISHES OF NEW ZEALAND.

By W. J. PHILLIPPS, F.L.S., F.R.G.S., and E. R. HODGKINSON.

THE present paper is a continuation of a previous one.* A record of fishes received by the Auckland Municipal Fisheries Company has been compiled for 1921, and based on this we have endeavoured to supply a certain amount of previously unpublished data, which as material cumulates will prove invaluable for purposes of biological research into the more intricate problems of food-supply and migrations.

The term "edible" as used in this and previous papers is applied to cover those indigenous fishes which have been actually found utilized as food by Europeans or Maoris. For easier reference the numbers given in the former paper have been retained. Five fishes have been added, one of which, *Zenopsis nebulosus*, is an addition to the fish fauna of New Zealand. The number of known indigenous edible fishes now stands at ninety.

Special reference has been made to the seven representatives of the family Salmonidae which have been successfully acclimatized in New Zealand.

Our thanks are due to Mr. L. T. Griffin, F.Z.S., of the Auckland Museum, for his ready co-operation and assistance, enabling us to treat with a larger number of species than would otherwise have been possible.

1. POLYPRION OXYGENEIOS. *Groper*, or *Hapuku.*

   During winter large numbers of young hapuku may be taken in Hauraki Gulf by trawling in water up to 40 fathoms. In a four-days trawl (July, 1921) around Mercury and Cuvier Islands one boat secured 3 tons of small hapuku. Adults received from line fishermen are not uncommon in Auckland, November to March. In Wellington the adult hapuku is not common during November and December, but the numbers gradually increase during January and February.

2. POLYPRION AMERICANUS. *Bass.*

   During the winter of 1921 bass were secured in Cook Strait up to 156 lb.

3. CAESIOPERCA LEPIDOPTERA. *Red Perch.*

   Taken in considerable numbers by trawlers in Hauraki Gulf during spring and summer months.

4. PARISTIOPTERUS LABIOSUS (= MACCULLOCHIA LABIOSUS). *Sowfish.*

   Small numbers were recorded in the Auckland market during April and September.

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* W. J. PHILLIPPS, Notes on the Edible Fishes of New Zealand, *N.Z. Journ. Sci. & Tech.*, vol. 4, No. 3, pp. 114–25, 1921.

5. ARRIPIS TRUTTA. *Kahawai.*

During June quantities of kahawai were taken by trawlers in Hauraki Gulf. This species did not appear in Auckland market during August and September, though recorded all other months of the year. The supply was abundant in Auckland from October to February.

7. LATRIDOPSIS CILIARIS. *Moki.*

Though at times plentiful in Hauraki Gulf, the supply of moki to Auckland markets is erratic and uncertain. It is generally taken by line boats, and is caught usually when the area trawled lies close to the kelp. On the northern part of the western coast of the South Island moki are unknown.

9. LATRIDOPSIS LINEATA. *Trumpeter.*

During November a small number of trumpeter was secured in Hauraki Gulf and recorded in Auckland. This species is very common at Jackson's Bay, where it may be secured up to 15 lb. weight. It is likely that the range of distribution of the trumpeter is wider than was previously indicated.

10. APLODACTYLUS MEANDRATUS. *Marble-fish.*

Generally known as "Maori chief" in Auckland, where quantities were received from line fishermen during March, May, and June. Odd examples were taken by trawlers in Hauraki Gulf during September and December. During the winter of 1921 specimens were received in Wellington from the Marlborough Sounds and sold as "Maori chief."

11. DACTYLOPAGRUS MACROPTERUS (= DACTYLOSPARUS MACROPTERUS). *Tarakihi.*

In Auckland tarakihi are abundant during all months of the year, being secured by trawlers as far north as East Cape. Sold as "moki" in Greymouth and Hokitika. In association with moki, tarakihi are plentiful off the White Bluffs, Blenheim; but unfortunately this locality is unsuitable for trawling.

12. DACTYLOPAGRUS DOUGLASII. *Porae.*

Small numbers of porae from 6 lb. to 15 lb. weight are exposed for sale in Auckland during the greater part of the year. This species has not been recorded in market during August, September, or October.

13. CHIRONEMUS SPECTABILIS. *Maratea.*

During the autumn of 1921 maratea were recorded in the Auckland market. They are apparently not so common as previously indicated.

14. GIRELLA TRICUSPIDATA. *Mangrove-fish*, or *Blackfish.*

Common in Auckland throughout the year. Sold as "blackfish." The supply is least from December to March, and greatest about midwinter. In December and January this species is often seen on the surface associated with school snapper, among which it appears to spawn.

17. PAGROSOMUS AURATUS. *Snapper.*

Plentiful in Auckland during each month of the year. On several occasions it has been shown that snapper from Hawke Bay and from around Kapiti Island deteriorate less quickly than do those of the warmer waters of the Auckland Province.

18. UPENEUS POROSUS (= UPENEICHTHYS VLAMINGII). *Red Mullet.*
Sold as "goatfish" in Auckland, where it is fairly common. Common at Great Barrier Island. It seems to live close to the shore and to prefer shallow water.

19. SCORPIS VIOLACEUS. *Maomao.*
This species was included in the former work, based on examples examined by the author at Bay of Islands. Mr. Griffin, of the Auckland Museum, informs us that both this species and the sweep (*Scorpis aequipinnis*) are sold as "maomao" in Auckland.

20. PSEUDOLABRUS COCCINEUS (= PSEUDOLABRUS MILES). *Spotty.*
Caught during all months of the year, but seldom seen in the Auckland market.

23. VERREO OXYCEPHALUS. *Spotted Pigfish.*
During the summer months both the banded and the spotted pigfish were recorded in Auckland. They were absent from the market from May to September.

25. ODAX VITTATUS. *Kelp-fish.*
Secured up to 3 lb. weight among butterfish, from which it is generally not distinguished.

26. CORIDODAX PULLUS. *Butterfish.*
During January, March, August, September, and October considerable numbers of butterfish were found to be arriving in Auckland. Butterfish were absent from market during the remaining months of the year.

27. CARANX PLATESSA. *Trevally.*
Trevally are to be found in the Auckland market throughout the year.

28. DECAPTERUS KOHERU. *Yellowtail.*
Common around the Auckland Provincial District. Large numbers are to be found in market during the early spring months.

29. TRACHURUS NOVAE-ZELANDIAE. *Horse-mackerel.*
Large numbers are smoked and sold in Auckland. In a smoked condition horse-mackerel is considered to resemble the Yarmouth bloater in flavour.

30. SERIOLA LALANDI. *Kingfish.*
Throughout the summer kingfish are fairly common in Auckland. From June to October they are rarely seen in market.

31. SCOMBER AUSTRALASICUS. *Southern Mackerel.*
Except during the months June to October, small numbers of these mackerel are received continuously in Auckland throughout the year. Sold as "Australian mackerel."

32. GERMO GERMON. *Long-finned Albacore.*
Examples up to 200 lb. weight secured on the west coast of North Auckland Peninsula have been reported to us.

33. GYMNOSARDA PELAMIS. *Bonito.*
Being a most active species, the bonito is rarely taken in the trawl. We have record of its appearance in the Auckland market during April.

34. THYRSITES ATUN. *Barracouta.*

The barracouta is common in Auckland throughout the year. It has been ascertained that this fish spawns in August.

35. JORDANIDIA SOLANDRI. *Southern Kingfish.*

Known as "tikati" to both North and South Island Maoris. "Tikati" was formerly considered to be synonymous with "para," the Maori term for frost-fish. Recorded in the Auckland market during most months of the year. The supply is largest during October, and least during June, July, and August.

36. LEPIDOPUS CAUDATUS. *Frost-fish.*

Except during April and July, when it is absent from market, the frost-fish is generally abundant in Auckland. All examples received by the Municipal Fisheries Company were secured by trawlers.

37. ENGRAULIS AUSTRALIS (= ENGRAULIS ANTIPODUM). *Anchovy.*

A few anchovy enter Auckland market in the spring, but are not greatly utilized as food.

38. SARDINIA NEOPILCHARDUS. *Pilchard.*

We have an unverified note of the appearance of this species in Auckland during October.

40. RETROPINNA RETROPINNA. *Smelt.*

The larval smelt, which has a strong cucumber-smell, is rarely sold as "whitebait." Canning-factories at Hokitika do not purchase any fish under the term "whitebait" other than the larval *Galaxias attenuatus*. Odd smelts may occasionally be detected among whitebait exposed for sale in Wellington.

41A. ANGUILLA AUCKLANDII. *Auckland Eel.*

Found in the Auckland market during November and December. This eel has a distribution extending over the whole North Island.

42. LEPTOCEPHALUS CONGER. *Conger-eel.*

Common in Auckland, October to April, but absent during midwinter and spring. Previously the conger-eel was stated to be rarer south of the North Island. Large numbers are common on the west coast of Otago.

45. GALAXIAS BREVIPINNIS. *Gudgeon.*

The name of "ngohongoho" is used by the Maoris of the Arawa Tribe to refer to this species.

46. GALAXIAS ATTENUATUS. *Minnow.*

All whitebait examined from Auckland were found to be referable to this species. Whitebait were exposed for sale in Auckland during August, September, and October.

50. HEMIRAMPHUS INTERMEDIUS. *Garfish.*

Recorded in the Auckland market during June and July only.

51. MUGIL CEPHALUS. *Grey Mullet.*

Common in the Auckland market from midwinter to October. Variously sold as "deep-sea" or "Auckland" mullet. Examples have been secured in spawning-condition at the end of November and during December.

52. AGONOSTOMUS FORSTERI. *Common Mullet.*

During February, August, and October small numbers of the common or estuary mullet were on sale in Auckland.

54. SERIOLELLA BRAMA. *Warehou.*

A few warehou were present in the Auckland market during April and October. These had been trawled in the Bay of Plenty. Around Wellington Province the warehou was formerly taken by line, but can now be secured only in the net. Fishermen at French Pass state that they occasionally still take this species on the line. At Bay of Islands warehou are unknown.

58. PHYSICULUS BACHUS. *Red Cod.*

Found in the Auckland market during September and October only. Not often trawled, on account of its inhabiting rocky portions of the sea-floor. Red cod are very plentiful at the Three Kings Islands, where they grow to a large size.

59. AUSTROBERYX AFFINIS. *Golden Snapper.*

During January, March, April, and May small numbers of golden snapper were received in the Auckland market. Mr. Griffin states that this species is very common in rocky localities around the Auckland Province.

62. CONGIOPODUS LEUCOPAECILUS. *Southern Pigfish.*

An attempt to sell this species under the name of "silver trumpeter" in Christchurch was unsuccessful.

63. ZEUS FABER. *John Dory.*

Common throughout the year in Hauraki Gulf. Except during February, when it is rarely seen, the John Dory is plentiful in the Auckland market during all months of the year.

63A. ZANCLISTIUS ELEVATUS. *Boarfish.*

At times this species is very plentiful in the Auckland market. Recorded at intervals during the summer months.

63B. ZENOPSIS NEBULOSUS. *Mirror Dory.*

During April the trawler "Nora Niven" secured small numbers of mirror dory in about 40 fathoms in Cook Strait. These fish agreed in all characters with those described by McCulloch.* They were sold in Wellington as "silver dory."

65. CAULOPSETTA SCAPHA. *Megrim.*

Except during May, June, and July, small numbers of megrim are constantly being received in Auckland. Most trawlers on a few days' cruise take odd specimens among other flat fish.

66. AMMOTRETIS GUNTHERI. *Brill.*

During July and August, 1921, large numbers were received in Wellington from Christchurch.

67. AMMOTRETIS NUDIPINNIS. *Turbot.*

During the spring months odd examples were secured by trawlers in Hauraki Gulf and sent into the Auckland market.

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* A. R. MCCULLOCH, Report on the Fishes obtained by the F.I.S. "Endeavour," *Zoological Results of the Fishing Experiments, Dept. of Trade and Customs, Australia*, vol. 1, pt. i, pp. 1–87, pls. i–xvi, figs. 1–20, 1911 (ref. to p. 83).

69. RHOMBOSOLEA PLEBEIA. *Sand-flounder.*

During May and June this species did not appear in the Auckland market, but was to be found in varying abundance during all other months of the year. During May we have found many of these flounders buried at considerable depth in the sand. In July numbers of adults were taken in the trawl. These were probably taking up their position for spawning purposes.

70. RHOMBOSOLEA MILLARI. *Yellow Flounder.*

During the summer the yellow flounder is found in considerable numbers in Auckland.

71. RHOMBOSOLEA TAPIRINA. *Green-back Flounder.*

Specimens have recently been identified from the neighbourhood of French Pass.

73. PELTORHAMPHUS NOVAE-ZEELANDIAE. *Sole.*

During each of the summer months small quantities of common sole appear in Auckland, but are rarely seen during winter. In March of each year large numbers of soles in excellent condition are secured off Hokitika.

74. CHELIDONICHTHYS KUMU. *Red Gurnard.*

Called "pihokahoka" by Maoris of the South Island. Commonly found in the estuaries of large rivers on the west coast of the South Island. At intervals small numbers may be seen exposed for sale in Auckland.

75. LEPIDOTRIGLA BRACHYOPTERA. *Gurnard.*

At irregular intervals throughout most months of the year numbers enter the Auckland market. This species is the common gurnard of Auckland.

76. PTERYGOTRIGLA PICTA. *Spotted Gurnard.*

During March and July small numbers of spotted gurnard appeared in the Auckland market. These had been trawled in the vicinity of North Cape.

78A. CHEIMARRICHTHYS FOSTERI. *Panokonoko,* or *Papane.*

During March Mr. Elsdon Best secured examples caught at Hiruharama, on the Wanganui River, North Island. Large numbers are annually secured by the Maoris of this locality. The panokonoko is much esteemed as a food fish.

79. PARAPERCIS COLIAS. *Blue Cod.*

Common in the Auckland market throughout the year. The supply is largest during winter.

81. GENYPTERUS BLACODES. *Ling.*

During December line fishermen in the Bay of Plenty forwarded a few ling to the Auckland market. On the west coast of the South Island ling are secured from November until the end of January.

82. CANTHERINES CONVEXIROSTRIS. *Leather-jacket.*

The trawlers take a continuous supply of leather-jacket into market in Auckland. Most are the above species, though some are undoubtedly *Cantherines scaber.*

85. SQUALUS FERNANDINUS. *Pioke.*

The pioke has been found in the Auckland market continuously throughout the year. It is popularly sold as "silver-strips," or "silver-spots." Probably many of the fish are *Mustelus antarcticus.*

86. GEOTRIA AUSTRALIS. *Lamprey.*

Called "piharu" and "korokoro" by the Maoris. Large numbers are taken annually by the Wanganui River natives during the run up-stream of this species, which in the North Island has been found beyond question to take place in June. A similar migration takes place in South Island rivers in October. During the run up-stream, June, 1921, several tons of this species were taken by Taranaki natives at a spot near New Plymouth.

SALMONIDAE.

(*a.*) SALMO FARIO. *Brown Trout.*

Throughout the South Island and in the southern parts of the North Island brown trout are commonly found in most rivers, lakes, and streams. The average size of the adult remains about double that of the same species in England. Brown trout in the thermal lakes of the North Island are rarely subject to disease. In most localities spawning takes place during July.

(*b.*) SALMO GAIRDNERI. *Steel-head Trout.*

Common in most North Island rivers. Numbers have been found in the North Island thermal lakes, where access to the sea is impossible. American authors consider the steel-head identical with the rainbow. Spawning takes place during July, August, and September.

(*c.*) SALMO IRIDEUS. *Rainbow Trout.*

I have used the term *Salmo irideus* to refer to the typical rainbow trout common in most large North Island thermal lakes. In Lake Taupo both the rainbow and the steel-head may be secured up to 10 lb. in weight. As far as has been ascertained, the steel-head and rainbow trout spawn together on the same ground.

(*d.*) SALMO IRIDEUS GILBERTI. *Californian Kern River Trout.*

This subspecies is generally characterized by abundant spots. Common throughout the North Island. It appears to have a greater resistance to disease than other trout.

(*e.*) SALMO IRIDEUS SHASTA. *Silver Trout.*

Common in Lake Taupo, where it is generally found on the eastern side. I have seen no examples over 6 lb. weight.

(*f.*) SALVELINUS FONTINALIS. *American Brook-char.*

Small numbers of char are found in many streams throughout both Islands. As this species is apparently unable to maintain itself in the struggle for existence against brown and rainbow trout, its acclimatization in most cases has not been fully successful. Spawning takes place during the early spring months.

(*g.*) ONCORHYNCHUS TSCHAWYTSCHA. *Quinnat Salmon.*

Through the zeal and untiring efforts of Mr. L. F. Ayson, Chief Inspector of Fisheries, the quinnat salmon is now thoroughly established not only in the Waitaki River, but also in most of the large rivers of the South Island. Recently quinnat salmon have been taken from several localities in the North Island.

HYBRIDISM OF *SALMO IRIDEUS* AND *SALMO FARIO* IN AUSTRALASIA.

By W. J. PHILLIPPS, F.L.S., F.R.G.S., Dominion Museum, Wellington, N.Z.

APART from the typical rainbow trout, New Zealand rivers and lakes contain several varieties or subspecies of rainbow trout sufficiently distinct from the typical form to be immediately recognized. Two of these subspecies in the thermal lakes are *Salmo irideus gilberti* and *Salmo irideus shasta*, and it is these which have gradually given rise to a popular idea that many of the trout in the lakes are hybrids between *S. irideus* and *S. fario*. My researches on the thermal-lakes trout lead me to the conclusion that little or no hybridism is taking place there, where in certain lakes rainbow and brown trout live together. Though the brown trout spawn a month or six weeks earlier than the rainbow, on occasions the spawning seasons of each may overlap.

Lack of literature on the subject of hybridism among Salmonidae prevents me dealing with the subject as fully as I would have desired. The instances in which a fertile hybrid trout has been produced are rare. Day (1884, pp. 30, 378, 585; and 1887, p. 255) has cited instances of hybrids between the American char and Loch Leven trout in which genital organs developed. Also Day (1887, p. 255) records the crossing of a male salmon and Loch Leven trout from which a number of hybrids were produced. From these hybrids a male was used at three years to fertilize three thousand Loch Leven trout-eggs, of which one or two hatched.

Richmond (1919, p. 72) states, "Personally I have met with no instances of brown trout and rainbow trout crossing. My attempts to cross them have always failed. I know water where the two kinds live together under natural conditions and where the spawning-time of the latest brown trout overlaps that of the earliest rainbows; but I have never seen in this water any fish which looked like a hybrid, nor have I seen the two kinds on the redds together.

"In France Dr. Joussell de Bellesmes, Director of Fish-culture in Paris, states (*La Pisciculture en France*, p. 168) that he obtained a successful cross at the Trocadero Aquarium in Paris on 3rd February, 1890, getting eight hundred ova which survived and developed satisfactorily, the majority of the hybrids resembling rainbow trout in outward appearance. Two of them lived in the aquarium till 1897, and grew to a good size, reaching a length of 85 cm., when in that year they spawned and died. It is curious that Dr. de Bellesmes has found a similar delay in arrival at sexual maturity in the cross, which is easily made, between the American brook-char and the brown trout, the hybrid from which in this country has usually been regarded as sterile."

EXPERIMENTS ON HYBRIDISM OF TROUT IN AUSTRALASIA.

Date.	Trout-hatchery.	Experimenter.	Trout.	Result.
1888–91	Masterton ..	L. F. Ayson ..	Brown ♂ × Rainbow ♀	No result.
,,	,, ..	,, ..	Rainbow ♂ × Brown ♀	20 per cent. hatched. A number were retained for three or four years, but none matured. Outside ray of pectoral fin white, second dark; general appearance like rainbow.
,,	,, ..	,, ..	American brook-char ♂ × Brown ♀	15 per cent. hatched, but many deformed. A number were kept six to seven years, but none arrived at sexual maturity.
1905 ..	Christchurch	Dr. Moorhouse	Brown ♂ × Rainbow ♀	No result.
,, ..	,,	,,	Rainbow ♂ × Brown ♀	Small number hatched, none of which arrived at sexual maturity.
1910–21	Hawera ..	A. Kean ..	Brown ♂ × Rainbow ♀	Many attempts, which gave no results.
,,	,, ..	,, ..	Rainbow ♂ × Brown ♀	Several attempts were failures, but from one lot 30 per cent. hatched in thirty-seven days, the average water temperature being 47° F. Many were considerably deformed with an abnormal umbilical sac. All died on the fourth day.
1918–20	Christchurch	M. H. Godby	Rainbow ♂ × Brown ♀	No result.
,,	,,	,, ..	Brown ♂ × Rainbow ♀	No result.
1919 ..	Masterton	J. G. Miller ..	Brown ♂ × Rainbow ♀	Two female rainbow stripped; no male rainbow available, but male brown secured and eggs fertilized. A small number hatched, which, being very weak, were later destroyed.
1920–21	Ballarat ..	V. R. Allan ..	Brown ♂ × Rainbow ♀ Rainbow ♂ × Brown ♀	Both ways tried with equal success in the hatching. Hybrids of brown male and rainbow female seemed the stronger. Eggs hatched on forty-first day. All young died a few days after the yolk-sac was absorbed.

The tabulated results of experiments performed in hybridism of trout are of great interest and importance. Six experiments of crossing brown ♂ and rainbow ♀ are enumerated. Four of these experiments gave no results; but the remaining two attempts were successful at least in the initial stages. The crossing of rainbow ♂ with brown ♀ was more satisfactory. Out of five experiments, four were successful in varying degree.

Whether it is only certain varieties of rainbow which will successfully cross with brown trout, or whether the state of sexual maturity of the parents, the temperature of the water, or other factors ultimately decide the relative success of the experiment remains yet to be proved.

The state of our present knowledge on the subject may be summarized as follows:—

1. Rainbow ♂ and brown ♀ may under certain conditions successfully cross.

2. Brown ♂ × rainbow ♀ are less likely to hybridize successfully.

3. Hybrid trout are a race of fish with a minimum vitality, which in a natural condition would rarely be able to compete in the struggle for existence.

4. It is possible for genital organs to develop in the hybrid and for these hybrids under artificial conditions, in rare instances, to arrive at a stage of sexual maturity.

5. Whether the progeny of hybrids could continue the race or not is unknown.

6. The many attempts made by Day with the crossing of races of trout tend to strengthen a view that hybrid trout when they occur naturally are unlikely to have any material effect on the races of Salmonidae with which they live, either during their own generation or in the future.

In conclusion, I wish to thank the gentlemen who have kindly supplied the information given in the preceding table, which contains, as far as I have been able to trace, the whole of the results of experiments in hybridism of trout in Australasia.

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A REVISION OF THE NEW ZEALAND BLEPHAROCERIDAE (ORDER DIPTERA),

With a Key to the Australian and New Zealand Genera, and Description of a New Species.

By R. J. TILLYARD, M.A., Sc.D. (Cantab.), D.Sc. (Sydney), C.M.Z.S., F.L.S., F.E.S.; Entomologist and Chief of the Biological Department, Cawthron Institute, Nelson, N.Z.

RECENT years have seen a great advance in our knowledge of the interesting family of net-veined midges, or Blepharoceridae, and the publication of papers by Lamb (1913), Bezzi (1913), and J. W. Campbell (1921) has laid the foundations of a sound understanding of those genera and species inhabiting Australia and New Zealand. Having collected these insects throughout New Zealand during the past two or three years, and also in Australia during a recent visit, it has become clear to me that the Blepharocerid faunas of the two regions have a common origin, and that the student who would understand the one should also study the other. Further, there appears to be, in the papers so far published, no agreement as to the homologies of the wing-veins. Lamb merely numbers the veins, while Bezzi and Campbell use the Comstock-Needham system, but interpret certain of the veins differently. There is also some confusion, due to Campbell, as to the correct genera in which certain species should be placed. As more work is sure to be done on this family in the near future, and more species are certain to be found both in New Zealand and Australia, it has seemed to me necessary to attempt to clear the ground at an opportune moment, by giving a short exposition of the true homologies of the wing-veins in this family, and also by publishing a convenient key to the genera found in both regions, and placing the known species in their correct genera. These are the two main purposes of this paper. A description of a new species of *Peritheates* has also been added, with a key to the known species of that genus.

My thanks are due to Mr. J. W. Campbell, of Christchurch, for the gift of valuable paratypes of his two species, recently described (1921).

THE VENATION OF THE BLEPHAROCERIDAE.

The most archaic existing genus, first discovered by Dusén in southern Chile and Patagonia, and more recently by myself in Australia, is *Edwardsina* Alex. (1920) (fig. 1, *a*), in which the venation is so complete that it seems impossible that anybody, after having studied it, could have any reasonable doubt as to the true homologies of the veins. Bezzi, of course, did not know of this genus when he wrote his paper, and his confusion of the true limits of M and Cu is quite excusable under the circumstances. Campbell, in spite of having a figure of *Edwardsina* before him, failed to realize the true limits of R and M, though he corrected Bezzi's original misconception on that point. Fig. 1 shows the correct interpretation of the veins in this genus, on the evidence given by both species of *Edwardsina*. It will be seen that there are three branches to Rs, and the only question

to be solved is whether the missing branch, R_4, was eliminated longitudinally by narrowing of the space between R_3 and R_5, or whether it disappeared towards the apex of the wing. In a long series of the Australian species of *Edwardsina* there is occasionally to be seen a stump-vein in the position indicated by *h*; and it seems a rea onable interpretation of this stump-vein that it is the last remnant of R_4. The posterior branch of Rs, then, is correctly R_{4+5} from its origin up to *h*, but should be labelled R_5 from *h*

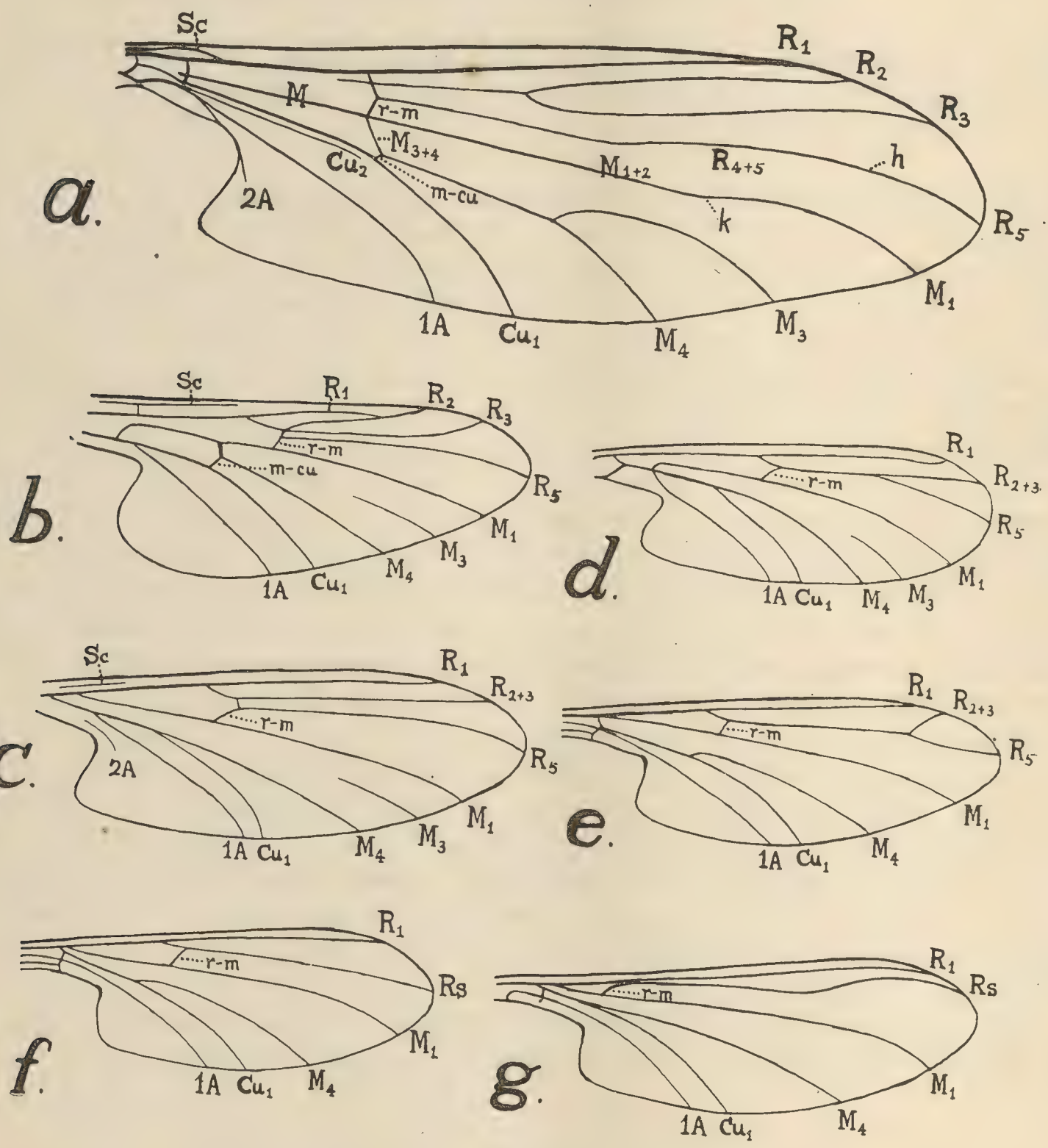

FIG. 1. — Wing-venation of — *a*, *Edwardsina* n. sp. from Australia; *b*, *Bibiocephala grandis* O.-S. (North America); *c*, *Liponeura cinerascens* Loew (Europe); *d*, *Philorus yosemite* O.-S (North America); *e*, *Neocurupira hudsoni* Lamb (New Zealand); *f*, *Peritheates turrifer* Lamb (New Zealand); and *g*, *Apistomyia* n. sp. from Australia. Comstock-Needham notation: *h*, point of origin of lost R_4; *k*, point of origin of lost M_2; *m-cu*, medio-cubital cross-vein; *r-m*, radio-median cross-vein.

to the apex. Turning to M, it will be seen that *Edwardsina* supplies the missing evidence required, in the form of a complete basal piece of M_{3+4}, not present in any other genus. We thus see that the connection of M_4 with Cu_1 is a secondary phenomenon, due to loss of this basal piece and fusion of M_{3+4} with Cu_1 at the point where it was originally attached by the short cross-vein *m–cu*; this cross-vein is actually already eliminated

in some Australian specimens of *Edwardsina*, leaving M_{3+4} attached to Cu_1, though still attached also to M itself by the existing basal piece. In both species of *Edwardsina* there is a strong kink on M_1 at the point *k*. I agree with Alexander in considering this as the point of origin of the lost vein M_2. The anterior branch of M, therefore, is correctly labelled M_{1+2} from its origin up to *k*, but M_1 from *k* to the margin. With respect to Cu, both species of *Edwardsina* show Cu_2 as a weak vein lying close below Cu_1, and only reaching about half-way from base to margin. Hence the next complete vein below Cu_1 must be 1A. Finally, *Edwardsina* offers a solution to the peculiar chitinous patch at the re-entrant angle near the base of the wing. For in the Australian species 2A is separate at the extreme base, but curves up to fuse with 1A for a short distance; it then leaves 1A and slopes downwards to the re-entrant angle, with which it fuses, and finally runs a short distance beyond it, as shown in fig. 1, *a*. A similar condition is to be seen in some specimens of *Paracurupira chiltoni* (fig. 2, *b*). The patch, then, is the swollen remnant of 2A still attached to the re-entrant angle after the rest of the vein has disappeared.

In order to understand the venation of the other Australian and New Zealand genera of the family it is easy to select a series of forms showing the gradual disappearance of various parts. This series is not actually a single evolutionary series, but it will serve to show plainly enough the stages of reduction. In *Bibiocephala* (fig. 1, *b*) the basal piece of M_{3+4} is retained, but M_3 becomes detached from its stem and appears as a separate marginal vein. In *Liponeura* (fig. 1, *c*) M_4 loses its basal piece and becomes attached to Cu_1 only, while R_{2+3} loses its fork and becomes a simple vein. In *Philorus* (fig. 1, *d*) the remaining fork of Rs moves distad, thus preparing us for the condition seen in *Neocurupira* (fig. 1, *e*), where, in addition, M_3 has completely disappeared. In *Peritheates* (fig. 1, *f*) the small distal fork of Rs has disappeared; while in *Apistomyia* (fig. 1, *g*) we find a further specialization in the upcurving of the distal end of Rs.

Two distinct developmental series are included in the above. Starting from *Edwardsina* as archetype, we have on the one hand the evolutionary series *Bibiocephala-Liponeura-Philorus*, confined to North America and Europe, and including, of course, *Blepharocera* also (not figured, but very similar to *Liponeura* in venation), in which the marginal vein M_3 is retained. These four genera form the subfamily Blepharocerinae proper; while *Edwardsina* itself is perhaps best considered as the single representative of an older subfamily, Edwardsininae. The remaining genera, *Neocurupira-Peritheates-Apistomyia*, together with *Hammatorrhina* Loew and the new genus *Paracurupira* defined in this paper, form a quite distinct series confined to Australasia for the most part, but with the most specialized genera, *Apistomyia* and *Hammatorrhina*, reaching out through the Oriental region as far as southern Europe. They are distinguished by having no trace of M_3, strong reduction of Rs (simple, or with short distal forking), long slender proboscis with forked tips to the labellum, and maxillary palpi reduced to one or two segments only. These genera form the true subfamily Apistomyiinae; their origin is not to be sought from or near *Philorus*, but from the lost stem out of which the South American genus *Curupira* arose as a side branch. They must have reached Australasia, in company with *Edwardsina*, through a temperate Antarctica, probably as early as the Jurassic period.

KEY TO THE AUSTRALIAN AND NEW ZEALAND GENERA.

1.	Rs and M both three-branched, M_{3+4} still connected basally with M as well as with Cu_1. Maxillary palpi with four or five segments	*Edwardsina* Alex.
	Rs simple or with a small apical fork, M only two-branched, the connection of M_{3+4} basally with M completely lost, and this vein secondarily attached to Cu_1. Maxillary palpi very short, with only one or two segments ..	2.
2.	Rs with a small apical fork; antennae with 14–15 segments; tarsal claws without teeth	3.
	Rs simple; antennae with 10–12 segments; tarsal claws with one or more teeth	4.
3.	Eyes of the male holoptic; anal angle of forewing very prominent	*Neocurupira* Lamb.
	Eyes of the male dichoptic; anal angle of forewing obtuse and weakly formed	*Paracurupira* n. g.
4.	Eyes of the male holoptic; antennae 10-segmented; tarsal claws with several teeth; Rs curving sharply up distally so as to end close to R_1, a long way before the apex of the wing	*Apistomyia* Big.
	Eyes of the male dichoptic; antennae 11–12-segmented; tarsal claws with a single basal tooth; Rs running almost straight, so as to end up far from R_1 and very close to the apex of the wing	*Peritheates* Lamb.

Genus PARACURUPIRA n. g. (Fig. 2.)

Characters as given in the above generic key. Allied to *Neocurupira* Lamb, and to *Curupira* F. Müller. It agrees with both genera in the general plan of the wing-venation (fig. 2, *a*, *b*), in which Rs has a small terminal fork, and also with *Curupira* in possessing the weak, obtuse anal angle, presumably an archaic character, whereas *Neocurupira* has this angle very prominent and strongly formed. It also agrees with both these genera, and also with *Edwardsina*, in having the large number of 14 to 15 segments in the antennae (fig. 2, *d*). It differs from *Curupira*, as does *Neocurupira* also, in having very small, two-segmented maxillary palpi (fig. 2, *c*); the palpi in *Curupira* are long. *Curupira* has short tips to the labellum and short hind legs; both *Neocurupira* and *Paracucupira* have these parts very long. The complete course of vein 2A (fig. 2, *b*) is not indicated by Campbell for the type specimen of *P. chiltoni*, but is clearly visible in a paratype received from him.

Genotype.—Curupira chiltoni J. W. Campbell.

Campbell was clearly correct in emphasizing the fact that this species did not belong to *Neocurupira* (genotype, *N. hudsoni* Lamb). But in placing it in *Curupira* he selected a genus from which it was even further removed, the only character common to the two, besides the wing-venational scheme, being the weak obtuse anal angle of the wing.

Postulating a South American origin for the Blepharoceridae as a whole, with an archetype not much different from *Edwardsina*, it is easy to see the evolutionary connection between the three genera *Curupira* (Brazil and Chile), *Paracurupira* (New Zealand), and *Neocurupira* (Australia and New Zealand). They are all considerably more highly specialized than the North American *Blepharocera* and *Bibiocephala*, but *Curupira* has kept the long maxillary palpi retained in those genera, together with the short hind legs, while in the evolution of the labellum also it has not proceeded as far as the Australian and New Zealand genera allied to it. As the common ancestor of the three genera must have had dichoptic eyes, it is thus clear that there must have been a dichotomy between the South American

Curupira, which has attained holoptic eyes, but is otherwise comparatively archaic, and the New Zealand *Paracucupira*, which retains the dichoptic eyes but is otherwise comparatively specialized. The specializations in this genus might be expected during its long journey from its country of origin, probably through a temperate Antarctica. In this connection it is interesting to note that the Australian species of *Edwardsina* shows certain specializations over the genotype *E. chilensis* Alex. from Chile and Patagonia. *Neocurupira* is certainly a direct offshoot of *Paracurupira*, having gained holoptic eyes and prominent angle of the wing. As this genus occurs in both Australia and New Zealand, it is a reasonable supposition that *Paracurupira* will yet be recorded either from Australia itself or from Tasmania. Finally, it is also quite logical, on imaginal characters, to claim *Peritheates* as a

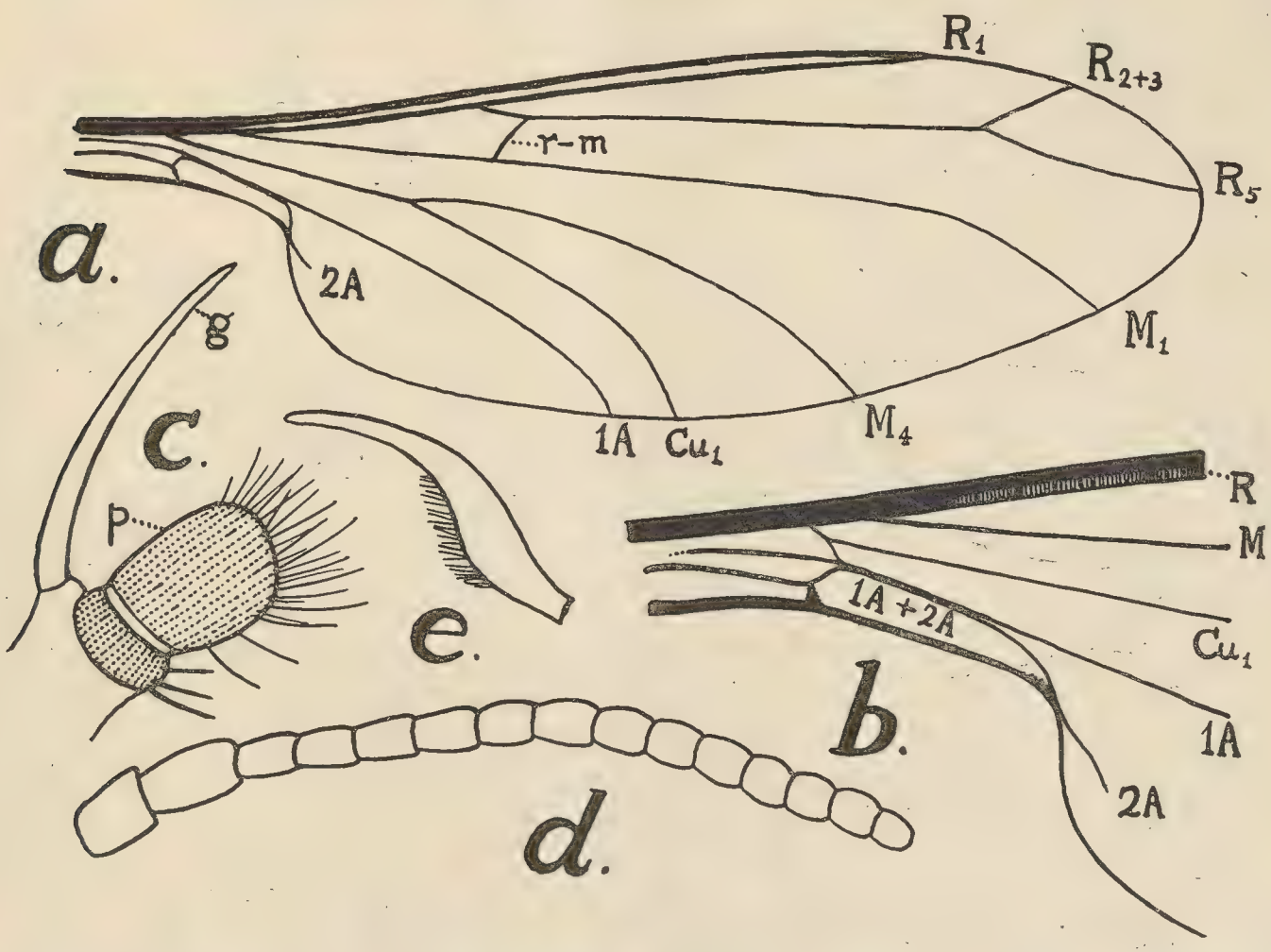

FIG. 2.—*Paracurupira chiltoni* (Campbell). *a*, wing-venation (× 12); *b*, base of wing (× 24), to show course of 2A; *c*, maxilla (× 112), showing galea (*g*) and two-segmented palp (*p*); *d*, outline of antenna (× 67); *e*, tarsal claw (× 112). All drawn from dissected paratype male sent by Mr. J. W. Campbell from Purau.

specialized offshoot from *Paracurupira* by loss of the apical fork of Rs and reduction of the antennae (but not from *Neocurupira*, since it does not possess the holoptic eyes of that genus), while *Apistomyia* would appear to be a further specialization from *Peritheates*, having gained holopticism independently, together with further reduction of the antennae and specialization in the form of Rs.

Genus PERITHEATES Lamb. (Fig. 3.)

Characters as given in the generic key above, to which should be added the very large and prominent ocellar turret, the keeled face, the single basal tooth on the tarsal claws (fig. 3, *k*), and the reduction of the number of antennal segments to 11 or 12.

Genotype.—Peritheates turrifer Lamb.

Apistomyia harrisi J. W. Campbell must be included within this genus, for the following reasons: In *Apistomyia* (genotype, *A. elegans* Bigot)

the eyes of the male are strongly holoptic, the ocellar turret very small and inconspicuous, the antennae only 10-segmented, the tarsal claws carry a series of strong internal teeth, and Rs turns up sharply distally so as to end up close to R_1, far from the apex of the wing. Campbell's species has dichoptic eyes, a very prominent ocellar turret, 12-segmented antennae, only a single basal tooth on the tarsal claws (fig. 3, *k*), and Rs of the normal

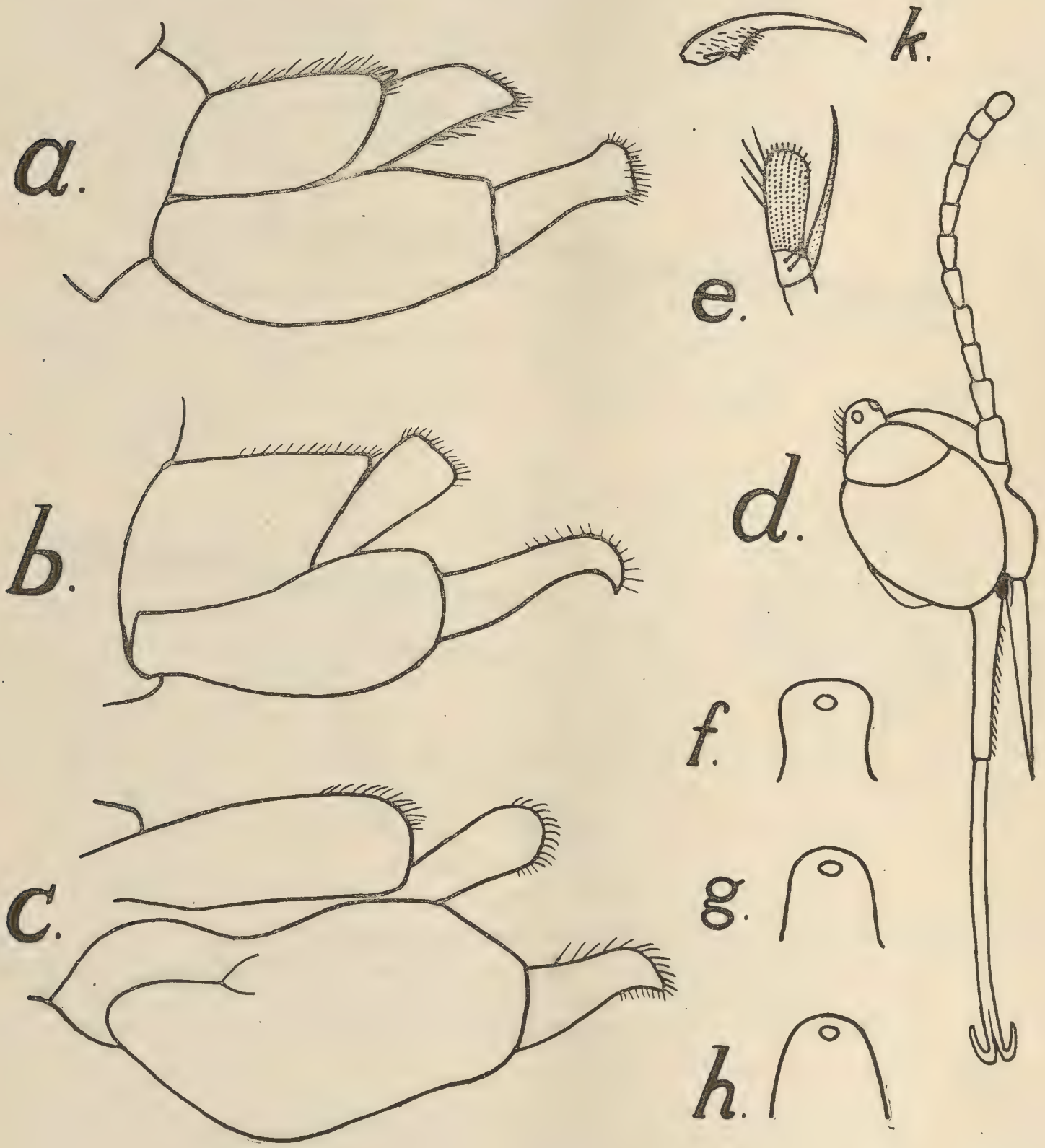

FIG. 3.—Genus *Peritheates* Lamb. *a–c*, hypopygia of males (× 56); *a*, *P. turrifer* Lamb, topotype from Arthur's Pass, taken by R. J. Tillyard; *b*, *P. intermedius* n. sp.; *c*, *P. harrisi* (Camp.), paratype from Ohakune, sent by Mr. J. W. Campbell; *d*, head of *P. intermedius* n. sp., lateral view (× 34), showing shape of antenna and ocellar tubercle; *e*, *P. intermedius* n. sp., maxilla (× 112); *f–h*, front views of ocellar tubercles (× 75); *f*, of *P. turrifer* Lamb; *g*, of *P. harrisi* (Camp.); *h*, of *P. intermedius* n. sp.; *k*, *P. turrifer* Lamb., tarsal claw (× 112).

form for the genus *Peritheates*; in fact, it only differs from the genotype *P. turrifer* in its larger size, stouter build, and in minor morphological details of specific value, such as the shape of the turret, antennal segments, hypopygium of the male, &c. It is difficult, indeed, to understand why Campbell placed this species in *Apistomyia*, seeing that he must have been familiar with its main characters from the works of Bigot and Bezzi.

Besides the two species mentioned above, I now add a third, discovered recently at Nelson.

KEY TO THE KNOWN SPECIES OF PERITHEATES.

1.	Larger species (forewing about 8 mm.), of rather stout build	*P. harrisi* (Camp.).
	Smaller species (forewing about 6 mm.), of very slender build	2.
2.	Ocellar turret constricted at base; abdominal segments bordered posteriorly with orange	*P. turrifer* Lamb.
	Ocellar turret not constricted at base; abdominal segments 2–4 bordered posteriorly with silvery-grey, rest black ..	*P. intermedius* n. sp.

Peritheates intermedius n. sp. (Fig. 3, *b*, *d*, *e*, *h*.)

♂ about the same size and shape as *P. turrifer* (forewing 6 mm.), but differing from it in the following characters :—

Antennae black, the two apical segments appearing silvery-grey owing to dense pubescence of that colour; number of segments 12, though the division between the last two is not always complete. Ocellar turret differently shaped, not constricted at base, but tapering a little in breadth from base to apex, which is well rounded (fig. 3, *h*). Face dull brownish-black. Maxillary palpi shorter and broader. Thorax black with scarcely a trace of grey on notum and very little on pleurae, posterior angles and margin of mesonotum bordered with fulvous. Wings slightly fulvous at bases; anal angle much more rounded than as shown in Lamb's figure of *P. turrifer*. Rs slightly sinuous distally, curving very slightly but definitely upwards before reaching margin. Pedicel of halteres dull fulvous. Tibiae weakly but definitely hairy (practically smooth in *P. turrifer*). Metatarsal segments of all legs shorter than in *P. turrifer*, that of fore leg less than the three succeeding segments taken together, that of middle leg little more than the two succeeding segments taken together, and that of hind leg not quite as long as the four remaining segments taken together. Abdomen black; segments 2, 4 with posterior margins broadly marked in silvery-grey. Hypopygium differs from that of *P. turrifer* as shown in fig. 3, *a*, *b*.

♀, forewing 6·5 mm., strongly infuscated all over, broader than in ♂. Mesonotum with two longitudinal greyish bands. Legs greyish-brown, shorter than in ♂. Abdomen jet-black, stouter than in ♂, tapering posteriorly, and ending in a pair of closely appressed, vertical, broadly subtriangular plates with slightly rounded tips, the distal portions fulvous.

Types. — Holotype ♂, allotype ♀, and series of paratype ♂♂, in Cawthron Institute collection, Nelson.

Locality.—Waterfall above Reservoir, Nelson, N.Z.

LITERATURE QUOTED.

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BEZZI, M., 1913. Blepharoceridi Italiani, &c., *Bull. Soc. Ent. Ital.*, vol. 44, 1912, pp. 1–114.

CAMPBELL, J. W., 1921. Notes on the Blepharoceridae of New Zealand, *Trans. N.Z. Inst.*, vol. 53, pp. 258–266.

LAMB, C. G., 1913. On Two Blepharocerids from New Zealand, *Trans. N.Z. Inst.*, vol. 45, pp. 70–75.

The Australian species *Apistomyia collini* Bezzi is described on p. 67 of Bezzi's work quoted above, while three new species, belonging to the genera *Edwardsina*, *Neocurupira*, and *Apistomyia* respectively, are described by me in a paper sent to the *Australian Zoologist* for publication last January. I have refrained from using the names of these species in this paper, owing to its not having been published at the time of writing.

AN EEL FIESTA.

By ELSDON BEST, Dominion Museum.

Photograph by J. McDONALD.

THE photograph shows a portion of the *marae*, or plaza, of the hamlet of Koriniti, on the Whanganui River. Te Pokiha, headman of the Komiti Marae, or Plaza Committee, has just apportioned a catch of eels among the various families of the hamlet.

In Maori estimation the eel is one of the more important of the offspring of Tangaroa. Not only did it provide a highly prized article of food, but it also has a place in Maori mythology, where it takes the place of the snake

of some other lands. Curious to relate, the Maori has apparently preserved the name of the old eel-god of India, where Ira, the eel-god, was symbolized by a phallus with a lunar crescent on its head. This name reappears as Ila in Babylonia. Another name for the eel-god in India is Indra, but in Persia Indra was the serpent, so that eel and serpent were confused even in regions where both were known. The phallic serpent of southern Asia reappears as the phallic eel of Polynesia and New Zealand. Even in the far-distant Mortlock Group the eel (*tiki-tol*) occupies the place of the serpent in the Babylonian myth of the Garden of Eden. In the Taranaki version of the myth the first woman on earth was evolved from a reflection, and became the wife of Tiki, the first man. Then Tuna (the eel) makes his appearance, and he is the tempter of the first woman. Scan the two Maori names (*tara puremu* and *hiku rekareka*) for the tail

of an eel and you have the key to this old myth that has travelled round the earth.

There was much work pertaining to the taking of the eel in former days. The various methods, and the finely constructed eel pots and corfs manufactured by natives, form an interesting study. The Maori did not fish for eels with a hook, but used a bob or a spear, and in some cases took them by hand. His eel-pots were not always set at weirs; they were not infrequently set in the open river or lake. The Whanganui and Waikato modes of using eel-pots differ widely.

The Maori is much given to the use of fat foods, and hence a dish of eels is greatly appreciated by him. In former times, when required for immediate use, they were cooked in the *umu*, or steaming-pit, and when large quantities were taken they were smoke-dried for future use. In the *kope* method of cooking, eels are wrapped round with leaves ere being placed in the oven. The skinning of eels prior to cooking was not considered necessary by the Maori.

DEPARTMENTAL REPORT.

Preliminary Report on the Resurvey of the Waihi Goldfield.

By P. G. MORGAN, Director of the Geological Survey.

INTRODUCTION.

FROM the 17th November, 1921, until the 23rd January, 1922, I was occupied in a resurvey of the Waihi Goldfield. In this work I was assisted by Mr. H. A. Ellis, Temporary Field Assistant.

The principal reasons for the resurvey were: (1) As time went on some of the conclusions advanced in *N.Z. Geological Survey Bulletin No. 15* * were found to be untenable, and others at least highly doubtful; (2) new data afforded by the deeper workings of the Waihi and Grand Junction Mines have become available during the past ten or eleven years; (3) the marked though perhaps not great evolution of new methods and more especially of new ideas in the science of economic geology during the decade 1911–21 has rendered reconsideration of Waihi geology advisable; (4) since 1911 work in the deeper levels of the Waihi and Grand Junction Mines, while continuing to yield considerable amounts of payable ore, has failed to reveal any of those high-grade ore-bodies known as bonanzas, and therefore it was desirable to ascertain if geological reasoning would point to the presence or absence of such ore-bodies either in depth or in areas laterally outside the ground already explored.

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* J. M. BELL and COLIN FRASER, The Geology of the Waihi-Tairua Subdivision, Hauraki Division, *N.Z. Geol. Surv. Bull. No. 15*, 1912.

The area examined during the survey consisted of a belt of country several miles wide, extending from Owharoa, five miles west of Waihi, to Waihi Beach, five miles to the east. The workings of the Waihi and Grand Junction Mines were in part closely examined, and it is intended to make further underground exploration before the main report is finally drafted. Brief visits to Karangahake, Golden Cross, and Maratoto were also made.

The present interim report gives some of the conclusions reached during the resurvey. It is not possible as yet to give reasons in full for these conclusions, and therefore the statements made will appear somewhat dogmatic, especially where criticism of former work is necessary.

TOPOGRAPHY.

The central point of interest at Waihi is Martha Hill,* inconspicuous and barren-looking, but traversed by lodes from which several millions of tons of highly profitable ore have been extracted. Standing on this hill, one sees to the north ridges, originally all densely bush-clad, rising to heights of over 2,000 ft. Westward, eight miles away, is the bold mass of Karangahake Hill (1,775 ft.), from which a prominent ridge runs south to Mount Te Aroha (3,126 ft.), the highest point of the Hauraki Goldfield. Near at hand—east, south, and west—the town of Waihi, with its numerous gardens and trees, is spread out in an irregular sheet, merging into the nearly level area generally called the Waihi Plain. This, bounded on all sides by hills, is the upper valley of the Ohinemuri River. It was once a waste of bracken fern and stunted manuka, but much has been brought under cultivation, and now numerous farmhouses, set in green fields, meet the observer's eye. Southward, beyond the plain, Hikurangi Hill (1,303 ft.), a barren irregular mass of rhyolite scantily clothed with vegetation, is the most prominent feature. Eastward are several hills, rising to heights of 700 ft. to 900 ft., beyond which is a low range, forming the water-parting between the Ohinemuri and the sea. This drops suddenly and steeply to the sea, which, except for the sandy beaches of Orokawa, Boat, and Homunga Bays, is here bordered by rugged cliffs. These extend far to the north, but southward give way to a long sandy beach (Waihi Beach).

In this preliminary report mention of many details of the topography must be omitted, but two points deserve emphasis. One is that, as shown in 1913 by Henderson (*Bull. No. 16*, p. 22), the Waihi Plain is essentially the much-eroded upper valley of the Ohinemuri River. In late geological times this stream and its tributaries, owing to a slight rejuvenation due to the down-cutting of the Karangahake Gorge rather than to elevation, have cut many distinct though not conspicuous terraces or benches in the soft rocks of the Waihi Plain.

The second point is of a purely economic character—the influence of topography on ore-deposition. This is given due emphasis by Bell and Fraser (*Bull. No. 15*, pp. 65, 142), and is mentioned here chiefly in order to point out that the ancient topography as well as the modern must be known if the probable distribution of ore in the lodes is to be predicted.

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* Maori name "Pukewa," according to J. McCombie in an article in the *Mining Magazine*, vol. 8, pp. 136–40, 1913.

GENERAL GEOLOGY.

The rock sequence in the Waihi Goldfield is shown by the following table :—

Classification of *Bull. No. 15*, slightly abbreviated. (Bell and Fraser, 1911.)	Classification in this Report.	Approximate Age of Formations.
River-flats, river-terraces, swamp deposits, drifting sands, &c.	Soils and subsoils, stream-gravels, terrace-gravels, raised beaches, wind-blown deposits, &c.	Recent and Pleistocene.
Tertiary volcanic rocks of the "Third period": Rhyolitic tuffs, breccias, agglomerates, lava-flows	Younger rhyolitic flows and tuffs; rhyolitic intrusions	Pliocene (perhaps in part Pleistocene).
Tertiary volcanic rocks of the "Second period," or Beeson Island series: Andesitic and dacitic tuffs, breccias, and lava-flows	Younger andesitic and dacite flows and dykes; andesitic tuffs, intercalated shale, lignite, &c. (Beeson Island series)	Upper Miocene.
Tertiary volcanic rocks of the "First period": Andesitic, dacitic, and rhyolitic tuffs and lava-flows	Older andesites, quartz andesites and dacites; rhyolite; minor associated breccias and tuffs; intercalated shale, &c.	Miocene.
[Torehine series]	[Oamaru series (not known in Waihi district, but possibly exists in depth)]	Middle and perhaps Older Tertiary.
[Greywacke, argillite, &c. (not known in Waihi district, but probably exist in depth)]	[Greywacke, argillite, &c. (not known in Waihi district, but probably exist in depth)]	Trias-Jura.

The oldest rocks that can be inferred to exist in the Waihi Goldfield are greywackes, argillites, &c., of Trias-Jura age. Rocks of this age outcrop prominently in the northern part of the Hauraki Peninsula (see *Geol. Surv. Bull. No. 4*), but do not occur on the land-surface nearer Waihi than the Hangawera Hills, about ten miles south-west of Paeroa, and over nineteen miles west-south-west (as the crow flies) from Waihi. The nearest outcrops in a northerly (or, rather, north-westerly) direction are at and near Rocky Point, north of Thames. The Trias-Jura rocks probably lie at a great depth, perhaps over a mile, beneath the surface at Waihi, but the possibility of their being reached at some smaller depth —say, 3,000 ft.—should be borne in mind.

Resting on the supposed Trias-Jura basement, with or without interposed sedimentaries of Oamaruian age, is a great pile of volcanic rocks, consisting principally of flows of andesite, dacite, and rhyolite, interspersed with tuffs and breccias. Dykes and dyke-like masses occur, but are not very common. The oldest of these volcanic rocks, so far as known, are the much-altered quartz andesites* ("dacites" of

* In this report the name "quartz andesite" is applied to rocks of andesitic type containing phenocrysts of quartz and having a silica content under 65 per cent. The term "dacite" is applied to more siliceous rocks verging on rhyolite.

Bull. No. 15) in which the auriferous-quartz lodes of the Waihi district occur. The rocks outcrop only in two small areas, shown by the geological maps published with *Bull. No. 15*. The recent survey has shown that the boundary assigned to the western and more important of these areas requires modification.

In places the quartz-andesite flows are separated by thin layers of tuff and breccia. These are of importance only as aiding in the interpretation of the structure.

At Owharoa a spherulitic rock as much allied to the rhyolites as to the andesites covers an area of about two square miles north of the Ohinemuri River. It is much altered (propylitized), and contains a number of auriferous lodes. For the present this rock will be called "dacite." Again, at Waihi Beach a similar rock, which wherever seen is more or less silicified, also contains auriferous veins. Although this rock must be called a "rhyolite," it is very closely allied to the Owharoa dacite. It is certainly older than the andesites of the adjoining coastal range, although in *Bull. No. 15* it is regarded as younger.

Overlying the Waihi quartz andesites with marked unconformity is a series of andesitic flows, tuffs, and breccias, assigned in *Bull. No. 15* to the Beeson Island series. The division of this series into two groups, as in *Bull. No. 15*, is not improbably correct, but the field evidence in its favour is obscure. The Beeson Island rocks, as seen near Waihi, attain a great thickness. To the north they form hills rising to heights of over 2,000 ft. The flow andesites are almost wholly hypersthene andesites with some resorbed hornblende and a little sporadic quartz, not sufficient, as a rule, to entitle them to be called quartz andesites. Moderately quartzose andesites do occur, and in the Grand Junction Mine, at No. 1 chamber (315 ft.), No. 1 shaft, an andesite with spherulitic groundmass is encountered. This type of rock has not previously been recorded as occurring in the Waihi district.* Hypersthene-hornblende andesite with a little biotite forms the dyke-like mass of Black Hill. Rock of the same type outcrops about three miles south-west of Martha Hill, or a mile east of Waikino, forming an inlier in rhyolitic tuff ("wilsonite"). From the Queen of Waihi shaft (east of Waihi), north-eastward to Ngatitangata Road, and again some miles south-east of Waihi, on the north side of the road to Waihi Beach, hornblende-hypersthene andesites cover considerable areas. There is some doubt concerning the age of the Black Hill rock, but it seems best to correlate it with the other occurrences of hornblende-bearing andesite, which are certainly older than the rhyolitic rocks presently to be mentioned.

Andesitic tuff and breccia appear on the coast-line for over two miles, extending from the headland south of Orokawa Bay to the north side of Homunga Bay. At half a mile to a mile inland these rocks are overlain by flows of hypersthene andesite. Dykes of a fine-grained andesite showing but few phenocrysts appear at Boat Bay, near Homunga, and in the coastal cliffs to the south. A similar rock is seen at the north end of Waihi Beach, and for half a mile up Waihi Stream.

At several points some miles from Waihi layers of shale and even of lignite appear intercalated with the andesitic rocks of the Beeson Island series, but these are unimportant in connection with the economic geology of the district, and need not be further mentioned in this report.

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* Sollas has described a "spherulitic and glassy hornblende-hypersthene dacite" from the Whangamata track, nine miles north of Waihi. (See *Rocks of Cape Colville Peninsula*, vol. 2, pp. 29–30, 1906.)

Spherulitic rhyolite forms the barren hills two or three miles east of Waihi, and Mount Hikurangi, a few miles to the south. It also covers a considerable area north of Homunga. The gently rolling area south and south-west of Waihi, generally known as the Waihi Plain, is for the most part covered by a remarkable rhyolitic tuff, to which the special name of "wilsonite" was given by the late Mr. Alexander McKay. Its true nature was in doubt until a few years ago, when Dr. J. Henderson showed conclusively that it was not a flow rhyolite, as had been previously supposed by many observers. The "wilsonite" is penetrated and overlain in several localities by a rhyolite, which under the microscope exhibits a corrugated flow structure, and (if fresh) a good deal of tridymite in characteristic nests and aggregates.

GEOLOGICAL HISTORY: LAND-MOVEMENTS.

The consideration of various facts, most of them not stated in this report, leads to the following conclusions, all of which have more or less important bearing on the economic geology of the Waihi Goldfield.

In Middle Tertiary times (some millions of years ago) the Hauraki Goldfield became the scene of intense volcanic activity. A thick sheet of andesitic and dacitic rocks, principally as lava-flows, but partly in the form of tuffs and breccias, was deposited upon a land-surface consisting mainly of Trias-Jura strata (greywacke and argillite). That the basement rocks were then above sea-level is a doubtful statement, but is inferred from the belief that beds belonging to the older part of the Oamaru series at that time had probably been elevated and in part eroded, as is seen in the Coromandel district.* After the outpouring of the earlier andesites and dacites, volcanic outbursts, in the Waihi district at least, ceased for a long time. During this time the land was extensively eroded. Deep valleys were formed, and the ridges between reduced in height. It is certain that the land then stood at least 1,000 ft. higher above sea-level than it does to-day, and it may have been 3,000 ft. or 4,000 ft. higher. If so, it was a high mountainous region, extending far to the east beyond the outlying islands now seen in that direction, and this quite probably was the case. Whether any auriferous lodes had been formed at this time or not cannot be certainly stated, but the available evidence, though capable of another interpretation, on the whole indicates that lode-formation occurred during the next period of igneous activity.

Before the close of the Miocene a new series of andesitic and dacitic eruptions began, giving rise to the rocks of the Beeson Island series. Contemporaneously, or perhaps at an earlier time, the older quartz andesites were extensively fractured and faulted. Immediately thereafter auriferous-quartz lodes were formed in many of the fractures by ascending heated solutions, which also greatly altered or "propylitized" the quartz andesites for considerable distances from the main channels.

At Waihi, however, the rocks of the Beeson Island series were not so much fractured as the older rocks, nor were they propylitized or altered, except locally, to any extent. Moreover, not one of the quartz lodes is known to extend into the younger andesites. Formerly this was thought to show that lode-formation at Waihi began before the outpouring of the younger andesites. No eroded lode-outcrop, however, has been found at the contact between the lode-bearing quartz andesites and the younger andesites. Elsewhere in parts of the Hauraki Goldfield the rocks of the

* Alternatively it may be supposed that this part of the Hauraki region did not subside below sea-level in Oamaruian times.

Beeson Island series may be propylitized, and carry auriferous-quartz lodes, but, as stated, this does not seem to be the case at Waihi.

A period of erosion, during which there was little volcanic activity, followed the second series of eruptions. Deep valleys were again worn in the land-surface, and its general relief was greatly reduced by denudation.

Late in the Tertiary a third series of volcanic eruptions began. Extensive flows of spherulitic rhyolite were followed by great explosive outbursts, which gave rise to the peculiar rhyolitic tuff termed "wilsonite," as well as to tuff and breccia of a more ordinary type. Finally, a rhyolite in which tridymite is well developed was extruded at a number of points, and volcanic activity in the Waihi region practically ceased. By this time the eastern extension of the Hauraki Peninsula previously mentioned had disappeared, except for some outlying islands. Since then the land, in common with many other parts of New Zealand, has been depressed some hundreds of feet below its present level. After that it seems to have been raised in stages to 100 ft. or more above its present level, thus allowing the streams to excavate the lower parts of their valleys below the present sea-level. Then, owing to moderate depression, the sea entered the stream-valleys, as seen on the western side of Tauranga Harbour. In very late geological time, as shown by raised beaches at Orokawa and Waihi Beach, a small elevation took place. It is especially important to know at what time or times since the period of lode-formation the land stood at a higher level than it does to-day, for during those times there was opportunity for descending waters percolating through the quartz lodes to concentrate their metalliferous contents in certain parts, thus giving rise to local enrichments, but equally, of course, impoverishing other portions of the lodes. This matter will be further discussed in a later section of this report.

FAULTING.

Examination of the mine-workings at Waihi shows clearly that the earlier quartz andesites have been much shattered and faulted. This breaking-up of the country rock was a necessary condition for the formation of the numerous lodes and ore-bodies of the goldfield. The faults are probably of two ages—one, as inferred in the last sentence, prior to lode-formation, the other either contemporaneous with lode-formation or later. The younger faults are for the most part on the boundaries or outside the areas known to contain auriferous lodes, so that the latter are very little affected by faulting, and no serious dislocation of any vein has yet been found.

ROCK-ALTERATION.

The alteration of andesitic and dacitic rocks caused by hydrothermal waters and volcanic gases has been much discussed. Alteration thus caused, if at all pronounced, is termed "propylitization." It is now recognized that various other kinds of rock, if subjected to the action of hydrothermal solutions, may show changes resembling those seen in propylitized andesites and dacites, and consequently such rocks are also spoken of as "propylitized." The term "propylite" was first used by F. von Richthofen, who thus named the altered andesites of the Transylvanian goldfields, which he regarded as a distinct species of rock. A few years later Zirkel, under the same impression, applied the name to similarly altered andesites in the Comstock district. Though "propylite," as the name of a rock species, has long been rightly discarded, except by one

or two authors, the retention of this term as a general name for propylitized andesites and dacites is convenient and almost necessary. Its use need cause no confusion in the mind of the student if he accepts its modern meaning and refuses to consider it as a distinct species of rock.

The character and extent of propylitization vary much in one and the same mass of rock, and even in one and the same hand-specimen, but in general the same features are exhibited in every district where andesites or dacites have undergone propylitization, whether it be in the Hauraki Goldfield, or at Redjang Lebong in Borneo, or in Transylvania, or in Nevada (for example, in the Comstock, Goldfield, and Tonopah districts).

For the present the reader may be referred to *Bull. No. 15* for particulars of the alteration which the lode-bearing rocks of the Waihi district have undergone.

It should be mentioned here, however, that at Waihi and elsewhere in the Hauraki Goldfield alteration caused by descending surface waters is superimposed on propylitization to considerable depths.

INFLUENCE OF COUNTRY ON ORE.

As is well known, in the Hauraki Goldfield and many other mining districts the country (country rock) near productive lodes or portions of lodes usually shows certain more or less distinctive characters, causing it to differ in minor details from that near unproductive lodes. The miner, quickly recognizing these characters, uses them in his search for ore-bodies, and calls any rock exhibiting them "favourable" or "kindly" country. Further, when a lode passes from one rock into another of a distinctively different type—for example, from granite to slate—a change in its mineral contents almost invariably takes place.* In the Hauraki Goldfield most miners entertain the belief that minor changes in the country exercise a profound influence on the ore contents of the contained lodes. Such a belief assumes that the formation of "favourable country" preceded lode-formation. As, however, the alteration of the country undoubtedly proceeded from the lode-fissures outward, rock-alteration and lode-formation are the effects of a common set of conditions, and are due to the same or similar causes. Thus the effect is virtually mistaken for the cause, or, in proverbial language, the cart is put before the horse. Such statements as "The deposition of the precious metals is wholly dependent on this alteration to favourable country" and "It is impossible to doubt that the nature of the country [meaning the nature of the alteration] exercised a dominant influence on ore-deposition" are therefore fallacious. Whether the country is hydrothermally altered (propylitized) only, or oxidized by descending solutions as well, does not affect this statement. When ore bonanzas are found in Tertiary volcanic rocks the adjoining country, without exception, will be more or less altered, and will be pronounced favourable by the miner and the geologist. The cause of the ore is the cause of the "favourable" country, and it is not correct to say that "favourable" country (in the sense used by the Hauraki miners) is the cause of ore-deposition. The following rules applicable to mineral districts in Tertiary volcanic rocks may here be stated :—

(1.) A minor variation in the original nature of the country, as from one kind of andesite or dacite to another, will not appreciably affect the nature or amount of ore in the lodes.

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* See WALTER HARVEY WEED, The Influence of Country Rock on Mineral Veins, *Ore Deposits*, pp. 216–34, 1913.

(2.) Those changes or peculiarities in the nature of the country near the ore-bodies which the miner observes are not the causes of the ore-bodies, but are results of the same set of conditions as those that produced the ore-bodies; or, in some cases, are altogether independent of the ore-bodies and the causes that produced them, the association then being purely accidental.

It has been suggested that the brown oxidized country seen on the foot-wall side of the Martha (see *Bull. No. 15*, p. 148) and Edward lodes at the lower levels of the Waihi Mine is the cause of impoverishment in those lodes. Although it is quite true that impoverishment does take place, the cause is much farther to seek. By no possible logical and at the same time probable reasoning can the oxidized rock be held responsible for the absence or scarcity of profitable ore, but it may be that the absence of rich ore and the oxidation of the country are due to a common cause—leaching of the lode and the rock by descending surface solutions; and the probability of this explanation will be asserted in a later section of this report.

Again, the presence of thin layers of tuff, accompanied by carbonaceous material, has been thought to be the cause of some impoverishment in the lower levels of the eastern part of the Waihi Mine. The tuff is similar in composition to the quartz andesites that overlie and underlie it; therefore it cannot materially affect the character of the ore in the lodes.* As for the carbonaceous material, it would act as a precipitant for any gold and silver that came into contact with it. The fact that the tuff and carbonaceous material represent an ancient land-surface has been mistakenly supposed to be of great consequence. This matter will not be discussed fully here, and only the conclusion that can be drawn from observed facts will be stated—namely, that this old land-surface, and others that may exist, have had no material effect on ore-deposition, either in the Waihi or the Grand Junction Mine. Carbon or carbonaceous material has been observed or detected by analysis in some of the faults ("slides") in the Waihi Mine and in the quartz of the Martha lode. The carbon in these cases is probably of inorganic origin, and not derived from the vegetation of an old land-surface. There are hundreds of recorded occurrences of carbon (usually in the form of graphite) in mineral lodes, &c. Free carbon is present in the quartz of the Martha, Edward, and probably other Waihi lodes, though only in small amount, and cannot be regarded as of organic origin.

STRUCTURE OF THE LODE-BEARING QUARTZ ANDESITES.

Until 1912 the older or lode-bearing quartz andesites of the Waihi district were correctly regarded by all writers as a series of flows, but in that year Dr. J. M. Bell and Mr. Colin Fraser† advanced the hypothesis that the main ore-bodies were within an intrusive mass of dacite (quartz andesite of this report). A year or two later, however, the officials of the Waihi and Grand Junction Mines discovered layers of tuff and fine breccia, accompanied by carbonaceous matter, in the heart of the supposed intrusive mass, thus completely disproving Bell and Fraser's interpretation of the geology. Soon after, Mr. A. Jarman, Assistant Superintendent of the Waihi Grand

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* It should be noted also that the underlying rock is a quartz andesite similar in all essential characters (both original and secondary) to the overlying quartz andesites, which contain the rich ore-bodies that have made the Waihi Mine famous.

† The Geology of the Waihi-Tairua Subdivision, *N.Z. Geol. Surv. Bull. No. 15*, 1912. See pp. 125, 129, 130, 131, 132, 134, 140, 145, &c. In November, 1911, the *Mining Magazine* published a forecast of Bell and Fraser's hypothesis (vol. 5, pp. 333–34).

Junction Company, wrote an elaborate paper,* which may be justly considered as having given the *coup de grâce* to the hypothesis of an intrusive mass. Strangely enough, as Jarman remarks, *Bull. No. 15* gives no direct evidence whatever in support of the hypothesis, which when first mentioned is apparently only tentatively advanced. As the writing of the bulletin progressed the authors appear to have embraced their hypothesis more and more firmly, so that they mention it again and again without qualification, and finally it seems to become an article of belief, on which all advice as to future prospecting is based. During the recent resurvey of the Waihi Goldfield the writer, without success, endeavoured to find some substantial evidence favouring the hypothesis.

Actually, then, the lode-bearing rocks of the Waihi district consist of a series of quartz-andesite flows, with some intercalated tuff and fine-grained breccia, evidently deposited under water. Such beds, however, are known to occur in one horizon only. Material resembling tuff or fine-grained breccia has frequently been seen on the mine-tips, and has also been noted in the underground workings, but it cannot be confidently asserted that any of this represents surface-formed rock. On the contrary, autoclastic breccias, formed by fault movements, certainly occur. Such rocks in many cases are extremely difficult to distinguish from true subaerial breccias and tuffs.

Beds of water-sorted tufaceous material have been observed in the Waihi Mine at various points from No. 7 level (704 ft.) to No. 13 (about 1,578 ft.), and also in No. 4 shaft at 1,590 ft. below the collar. In every exposure the beds show a considerable dip (averaging between 25° and 30°) to the south-east. They are dislocated by various faults (including some of the lode-fissures), none of which, however, seem to have a large throw. Similar tufaceous beds appear in several parts of the Grand Junction Mine between No. 4 level (793 ft.) and No. 7 level (1,200 ft.), and, owing to being involved in the Empire lode fault, in the Central Empire stopes below No. 7 level.

Layers of tuff containing fragments of altered wood appear at a depth of 620 ft. to 640 ft. in the Grand Junction No. 1 shaft. These beds dip at 21° – 22° to the east of south. They rest on an eroded surface of the older quartz andesites, and are overlain by andesites of the "second period," or Beeson Island series. These facts form part of the evidence for the belief that most, if not all, of the tilting and faulting, as well as lode-formation, followed the extrusion of the Beeson Island rocks.

Earlier observers, including the writer, noted only a few unimportant faults in the lode-bearing quartz andesites, but recent work, as already mentioned, shows that faults are numerous, though none with large throw has been detected. The existence of more important faults, however, is suspected. These are probably of post-mineral age.

Summary of Structure.—Briefly, the Waihi lode-bearing rocks consist mainly of a series of andesitic flows, arranged with a decided dip to the south-east. These rocks are much jointed, and in places sheeted. They are traversed by numerous small faults, some of which are occupied by lodes. Most of the faults are earlier than or contemporaneous with the lodes, and accordingly do not dislocate them.

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* The Geology of the Waihi Grand Junction Mine, published about October, 1915, by the Institution of Mining and Metallurgy as a paper to be discussed at the meeting on the 21st October. See also the discussion on this paper, published later. The paper, with discussion, appears in *Trans. Inst. Min. and Met.*, vol. 25, pp. 3–58, 1916.

THE LODES.

In a report such as this it is not feasible to give an adequate description of the Waihi lodes, for their importance is so great that hardly any account could be too detailed. The reader is therefore referred to *Bull. No. 15*, of which pages 143–72, as well as many other pages, are almost entirely devoted to description of the auriferous veins, &c. Plans and sections will be found opposite pages 128, 168, and 172. A few general statements regarding developments in depth during the past ten years are desirable in order to supplement the admirable descriptions of the various lodes given by Bell and Fraser.

The Martha lode in the deeper levels of the Waihi Mine (and also of the Grand Junction Mine) in general maintains its size, though locally at No. 11 level (1,300 ft.) in the eastern part of the Waihi Mine it is thin. At No. 12 level (1,446 ft.), however, crosscuts show it to be from 58 ft. to 68 ft. wide. Below No. 8 level (854 ft.) the dip flattens from 80° to about 70°, and in the eastern part of the Waihi Mine, at, or even above, No. 12 level, junction with the Empire lode is imminent. To the west, near No. 2 shaft, the junction will be at No. 13 or a lower level. At or about 2,000 ft. the Martha may also be expected to junction with the Royal lode. Whether these junctions will have a material effect upon the ore contents remains to be seen, but, as shown below, hope of enrichment is justifiable.

Below No. 9 level the Martha lode as a whole has remained poor, though several blocks of low-grade ore have been mined. Between Nos. 9 and 10 levels a band of country on the hanging-wall, rich in veinlets carrying much sulphide of silver and appreciable gold, was stoped for some distance. At No. 11 level a veinlet in the hanging-wall country worth £21 per ton has been sampled, but is too thin to work, unless on being further prospected it should be found to increase in size. At this level the Martha lode as a whole is poorer than in any level above, but in No. 12 level it shows improvement. In some parts of the lode sulphides are fairly abundant, but there are also portions where the quartz is "oxidized"—*i.e.*, stained by oxides of iron and manganese. Contrary to some prophecies that have been made, little or no calcite has appeared in the Martha low levels. Since in many places the lode is rubbly and manganese oxides are plentiful, hope of "secondary" enrichment at greater depth may be entertained. More especially there is some likelihood of ore at the junction with the Empire, for this lode carries much calcite, which is an efficient precipitant of gold. If the calcite at this junction has been leached, then the hope of enrichment may be transferred to the Royal-Martha junction.

The Empire lode in the lower levels of the eastern part of the Waihi Mine maintains a respectable size. Westward, towards its junction with the Edward lode, it becomes small. In the Waihi Mine it is inclined to branch, and the same statement is true of the adjoining Dreadnought lode, so that the identification of the main Empire lode may in places be difficult. In the deeper levels, as in the higher levels, the Empire lode contains a good deal of calcite, and of quartz apparently pseudomorphous after calcite. Rich ore is almost absent. At or just below Nos. 12 and 13 levels, according to locality, the Empire lode will meet the Martha, and here, for the reasons already expressed, ore enrichment may occur in the latter. Since the Welcome and other lodes have junctioned with the Martha at higher levels, increasing its size, but failing to pass through it, the Empire will probably suffer the same fate.

In the Grand Junction Mine the Empire lode is in three branches, known as the hanging-wall, central, and footwall sections. Between No. 7 (1,200 ft.) and No. 8 (1,320 ft.) levels the central and footwall sections unite to form an almost vertical lode. Stoping between Nos. 7 and 8 levels is proceeding, but the ore as a whole is not rich. At No. 9 level (1,440 ft.) some fairly-good-looking ore is being broken. The curly banded quartz shows manganese-oxide stains, and is intermixed with a good deal of rhodochrosite (carbonate of manganese).

In the eastern part of the Waihi Mine the Royal lode is of good thickness, but the values fall away with depth. At No. 11 level the lode is unpayable near No. 4 shaft, but eastward the lode is being stoped for its full width of 15 ft. to 23 ft. The ore consists of a mixture of ordinary quartz, quartz apparently pseudomorphous after calcite, and calcite, with some sulphides and a little chlorite or similar material. At No. 12 level payable ore has not yet been found. Westward, towards its junction with the Edward lode, the Royal becomes thin. Its appearance at Nos. 10 and 11 levels suggests that primary ore has been reached, and that there is little hope of secondary enrichment at greater depths. The abundant calcite of the upper portions of the Royal lode indicates that enrichment by descending solutions cannot have taken place at lower levels, for calcite and allied carbonates precipitate gold. There is, however, the possibility of primary ore rich enough to be mined occurring at greater depth.

The Dreadnought lode, discovered since Dr. Bell's and Mr. Fraser's examination, has been worked at several levels with satisfactory results. It lies on the footwall (or southern) side of the Empire lode, but has a more northerly strike than the latter lode, and therefore junctions with it towards the east end of the Waihi Mine. A south branch was followed for some distance at No. 10 level, and found to develop into a payable ore-body consisting of ordinary quartz with a band of light-coloured friable material called "creamy quartz" in the mine (composition not yet determined) which gave high assay values (£6 per ton, &c.).

The Edward lode at No. 8 level was remarkably rich, a crosscut at a point where it was 70 ft. wide assaying on the average over £10 per ton. At No. 9 level it was much poorer, and at Nos. 10 and 11 levels it is again poorer, though still in part mineable. The rich ore at No. 8 level contained numerous blue veinlets of silver sulphide, a feature not seen at No. 11. Here much of the quartz is crustified or banded, and not of unfavourable appearance. Manganese oxides are present, but calcite was not observed. The chances of "secondary" enrichment in depth are fair, and in addition, or alternatively, there is the possibility of bonanza primary ore.

At the present time an exploratory crosscut, known as the Salmon, is being driven at No. 11 level in a north-west direction from the Edward lode. At higher levels the ground is traversed by the Welcome lode and branches of the Martha lode. In the uppermost of these levels the Welcome lode and, near the surface, some of the branches of the Martha were found to be payable, but exploration at lower levels down to No. 8 gave poor results. A large body of oxidized rock, as previously mentioned, extends from the surface to a great depth on the north (or footwall) side of the Martha lode and on the west side of the Edward. This, from its appearance, and from the fact that the Martha and Edward lodes become poor where, in the deeper levels, it impinges on them, has been regarded as "unfavourable" country. As seen in the Salmon crosscut, this oxidized rock is of a drab-purple colour, and is what every one with Hauraki Goldfield experience would term "poor-looking country."

However, several quartz veins have been intersected in the crosscut, and all contain a little gold. One, 12 in. in width, assayed £3 6s. per ton, and on close examination a little fine gold could be seen in the quartz, which is white, and contains inclusions of highly oxidized rock. Moreover, the fact that the country is oxidized shows that in a late geological period it was leached by descending surface waters, and if it should contain quartz lodes of any size the probability of a secondarily enriched bonanza at a somewhat lower level is considerable and even great.

Genesis of the Lodes.—In *Bull. No. 15* (p. 132) it is stated that the Waihi veinstone is the product of at least three different impregnations by mineral-bearing hydrothermal solutions. With this hypothesis, and particularly with the statement made on pages 60 and 132 to the effect that the first impregnation resulted in the deposition of carbonates only (mainly manganiferous calcite), the writer is constrained to disagree. The evidence collected during the recent resurvey and in earlier years is much more consistent with the view that there was only one distinct period of lode-formation by ascending hydrothermal solutions than with the view that there were two or more. Three non-metallic minerals are prominent constituents of the veinstone—namely, quartz, calcite, and valencianite (a variety of potash-feldspar). It can be definitely stated that calcite, whether manganiferous or not, does not precede quartz in order of formation. As a rule, it is practically contemporaneous with the latter, some being technically slightly earlier and some slightly later. In still other cases it appears to have been deposited by descending waters, and is therefore much younger than the primary-lode minerals. Valencianite is abundant in some parts of the lodes. In small veinlets traversing the country it commonly lines the walls, having been formed by a reaction between the vein-forming solutions and the country, and in such cases it appears to be the earliest-formed mineral. When it occurs in the central part of the veinlets, or in the larger lodes, it is always one of the primary minerals, formed contemporaneously with quartz and in many instances with calcite. Although a considerable amount of the vein material has been deposited in open spaces, the greater part has been formed by replacement of the country. This is contrary, in large measure, to the view expressed in *Bull. No. 15*, which gives replacement or metasomatic processes a minor position. In general the sulphides, with the part exception of pyrite, appear to be of later formation than the primary quartz, valencianite, and calcite of the lodes. Hence their formation may be ascribed to solution and redeposition by descending surface waters, a process which has resulted in local gold-silver enrichments of considerable importance. The extent to which enrichment has taken place is, however, open to discussion.

PROBABILITY OF DISCOVERING ORE BY LATERAL EXPLORATION.

The hypothesis advanced in *Bull. No. 15* that an intrusive mass of dacite contains the principal ore deposits at Waihi having been completely disproved, the probability of finding ore-bodies by lateral exploration is now much greater than the authors of that bulletin thought. In view of the great richness of the ground that has been worked in the Waihi and Grand Junction Mines, the careful prospecting of all propylitized quartz andesite outside the known lode-bearing area is thoroughly justifiable. In particular, the exploration of the western side of the Martha Hill, where oxidized rock extends to the greatest depth yet reached in mining operations, is strongly recommended. The probability of payable, and even bonanza, ore at or near the horizon where the

oxidized zone merges into the sulphide zone is considerable, and may even be great.

PROBABILITY OF DISCOVERING ORE IN DEPTH.

As is well known, outcropping ore-shoots in Tertiary volcanic rocks almost invariably end at depths of from a few hundred feet to 1,000 ft., though in a few cases they extend to 1,500 ft. In many mines, however, new ore-shoots, not outcropping at the surface, are found even at depths of 1,000 ft. or more, and some of these—rather rarely, it is true—reach depths of over 2,000 ft. At Cripple Creek numerous hidden ore-shoots have been found during mining operations. The most striking example of bonanza ore in depth appears to be the California and Consolidated Virginia ore-shoot, found towards the northern end of the Comstock lode at a depth of 1,250 ft. It extended to a depth of 1,950 ft., and is said to have yielded one-tenth of the entire production of the lode, or over £6,000,000 worth of gold and silver. The nearest surface shoot ended more than 1,000 ft. away. In view of the geological history of the Waihi Goldfield, and especially of its former elevation far above sea-level, the existence of rich ore at a depth of 2,000 ft. is not improbable, though it would be too much to postulate a bonanza so rich and extensive as that of the California and Consolidated Virginia.

Against the likelihood of payable gold and silver ore at great depth in Tertiary volcanic rocks is urged not only past experience, but the hypothesis of a critical level for ore-deposition determined by conditions of temperature and, to a less extent, of pressure. This view is advanced in *Bull. No. 15* (pp. 65, 142, 180). While it must be admitted that if the temperature of the ore-bearing solutions exceeded 365° C. (the critical temperature of water) ore-deposition would be unlikely, there appears to be no reason for supposing that the critical level has been reached at Waihi. Probably the original critical level as determined by temperature was over 5,000 ft. — possibly much more — below the then surface, and, after a liberal allowance for erosion since the period of lode-formation has been made, it was probably 4,000 ft. below the present land-surface. It is unlikely that the pressure at that depth would markedly retard ore-deposition. A striking decrease in ore-values has taken place at depths over 1,000 ft. or more, but other causes for this can be assigned, and they do not exclude but rather favour the view that shoots of payable ore will be found at still deeper levels.

If, however, exploration should be carried to 2,000 ft. without new ore-shoots being discovered further sinking would not be advisable. From this opinion probably no one will dissent.

SUMMARY.

The Waihi Goldfield has apparently reached the stage of old age, and the geologist has been asked to state whether its rejuvenation is possible. On the whole the verdict of the writer is favourable to a prolongation of the life of the field. Extensive lateral exploration, and sinking to a depth of about 2,000 ft., are recommended.

In order that a true perspective may be obtained, it is necessary in the first place to discard certain errors or probable errors and fallacies which have gained more or less vogue. Briefly, these are—

(1.) The hypothesis of an intrusive dacite or quartz-andesite mass which contains the more productive ore-bodies. This view, advanced in *Bull. No. 15*, has retarded lateral exploration. It may safely be regarded as wholly incorrect. The suggestion

made by Mr. H. F. Bain,* that in part the Waihi quartz andesites are sills, finds no support from the field or underground examinations made during the writer's survey. Jarman's view† is the same as that of the writer.

(2.) The hypothesis that the primary lode-filling consisted mainly of carbonates. Field and microscopic examinations satisfactorily disprove this view.

(3.) The hypothesis that most of the lode-material represents filling of open spaces.

(4.) The hypothesis of a critical level, so far as any depth yet reached is concerned.

(5.) The view that slight variations in the original nature of the enclosing rock may cause great variations in the amount and quality of the ore.

(6.) The fallacy that ore-deposition is dependent upon comparatively insignificant variations in the nature of the alteration undergone by the wall-rocks, the fact being that lode-formation and alteration of the wall-rocks are different though connected effects of the same causes.

(7.) Failures to distinguish between post-mineral changes and events, which cannot have had any bearing on the original ore-deposits but may have had much to do with the formation of "secondary" ore, and those changes or events which preceded or accompanied lode-formation.

Among the positive results of the resurvey are--

(1.) Some of the geological boundaries as previously mapped have been rectified, and various errors have been corrected.

(2.) The intrusive dacite or quartz-andesite hypothesis, it is hoped, has been finally shelved, and a return to earlier, more correct, views has been made.

(3.) The lode-bearing rocks have been found to be much faulted, and the significance of this in relation to lode-formation has been clearly ascertained.

(4.) A partly new hypothesis (not here stated) of lode-formation at Waihi has been evolved. This satisfactorily explains many of the observed facts, and to some extent favours deeper exploration.

(5.) Data supporting enrichment of portions of the lodes by descending solutions (so-called "secondary enrichment") have been obtained.

(6.) The policy of lateral exploration to the limits of the propylitized quartz andesites is shown to be sound.

(7.) Deeper exploration to perhaps 2,000 ft. is justified, for it can be shown (*a*) that secondarily enriched ore may exist to or near that depth (not, however, in lodes carrying much calcite), and (*b*) that new primary ore-bodies are a distinct possibility.

(8.) Since the ore-bearing quartz andesites have a general dip to the south-east, there is a possibility that ore-bodies at even greater depth than 2,000 ft. may exist in that direction.

(9.) The existence of a body or bodies of secondary ore at considerable depth in the western part of the Waihi Mine is shown to be probable.

(10.) The existence of secondary ore at considerable depth in the lodes of the Rosemont–Silverton hills and elsewhere, although not perhaps strongly probable, is shown to be more than a shadowy possibility.

Wellington, 14th February, 1922.

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* In discussion on Mr. A. Jarman's paper, previously mentioned.

† Expressed in answer to Mr. Bain. See p. 51 of publication previously cited.

ASTRONOMICAL NOTES.

Ephemeris of a Comet.*

By C. E. ADAMS.

IN an elliptic orbit it is sometimes desirable to express the co-ordinates in terms of a single variable—the eccentric anomaly—especially so when a large number of places has to be calculated. The constants required are calculated from the following equations † :—

$$\lambda_x \cos L_x = b \sin a' \cos A'$$
$$\lambda_x \sin L_x = a \sin a' \sin A'$$
$$v_x = -e\lambda_x \sin L_x,$$

where $A' = A + \omega$; and from similar equations involving y and z.

The co-ordinates are then given by the following equations :—

$$x_4 = \lambda_x \sin (L_x + E) + v_x \quad \ldots\ldots\ldots\ldots\ldots\ldots (A)$$

and by similar equations for y and z.

$$x = r\cos w \qquad y = r\sin w \qquad z = 0 \qquad (1)$$

$$x_1 = x\cos\omega - y\sin\omega \qquad y_1 = y\cos\omega + x\sin\omega \qquad z_1 = 0 \qquad (2)$$

$$x_2 = x_1 \qquad y_2 = y_1\cos i - z_1\sin i \qquad z_2 = z_1\cos i + y_1\sin i \qquad (3)$$

$$x_3 = x_2\cos\beta - y_2\sin\beta \qquad y_3 = y_2\cos\beta + x_2\sin\beta \qquad z_3 = z_2 \qquad (4)$$

$$x_4 = x_3 \qquad y_4 = y_3\cos\epsilon_0 - z_3\sin\epsilon_0 \qquad z_4 = z_3\cos\epsilon_0 + y_3\sin\epsilon_0 \qquad (5)$$

$$\left.\begin{aligned} x_4 &= (\cos\omega\cos\beta - \sin\omega\cos i\sin\beta)x - (\sin\omega\cos\beta + \cos\omega\cos i\sin\beta)y \\ y_4 &= \{(\sin\omega\cos i\cos\beta + \cos\omega\sin\beta)\cos\epsilon_0 - \sin\omega\sin i\sin\epsilon_0\}x \\ &\quad + \{(\cos\omega\cos i\cos\beta - \sin\omega\sin\beta)\cos\epsilon_0 - \sin\omega\sin i\sin\epsilon_0\}y \\ z_4 &= \{\sin\omega\sin i\cos\epsilon_0 + (\sin\omega\cos i\cos\beta + \cos\omega\sin\beta)\sin\epsilon_0\}x \\ &\quad + \{\cos\omega\sin i\cos\epsilon_0 + (\cos\omega\cos i\cos\beta - \sin\omega\sin\beta)\sin\epsilon_0\}y \end{aligned}\right\} \qquad (6)$$

$$\left.\begin{aligned} x_4 &= P_x x - P_y y = r(P_x\cos w - P_y\sin w) \\ y_4 &= Q_x x + Q_y y = r(Q_x\cos w + Q_y\sin w) \\ z_4 &= R_x x + R_y y = r(R_x\cos w + R_y\sin w) \end{aligned}\right\} \qquad (7)$$

$$\left.\begin{aligned} x_4 &= aP_x\cos E - aeP_x - bP_y\sin E \\ y_4 &= aQ_x\cos E - aeQ_x + bQ_y\sin E \\ z_4 &= aR_x\cos E - aeR_x + bR_y\sin E \end{aligned}\right\} \qquad (8)$$

ERRATUM.—In equation (6) for y_4 the final "sin ω" should be "cos ω."

This method is shorter and simpler in application than that described previously, but the labour of forming and solving the nine extra equations is still considerable.

So far the work has proceeded on conventional lines and in accordance with the standard treatises on dynamical astronomy by Watson, Moulton, and Plummer. But it was felt that the labour of forming and solving the

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* See also "Astronomical Notes," this *Journal*, vol. 4, No. 4, August, 1921, p. 191.

† JAMES C. WATSON, *Theoretical Astronomy*, p. 94: Philadelphia, J. B. Lippincott Co., 1900.

two sets of equations, fifteen in all, might well deter beginners from undertaking such calculations, and accordingly search was made for a simpler method, with fortunately a happy result.

The heliocentric equatorial co-ordinates are readily derived; thus the co-ordinates of the comet in the plane of the orbit are given in equations (1), where the Sun is the origin, the axis of x is the line of apsides, r is the radius vector, and ω is the true anomaly. If the axes are rotated in the plane of the orbit until the line of nodes is the axis of x, then the co-ordinates are given in (2), where ω = perihelion minus node = $\pi - \Omega$.

Rotating the axes about the line of nodes until Oy_1 becomes Oy_2 in the plane of the ecliptic and Oz_2 is directed towards the north pole of the ecliptic gives the co-ordinates in (3), where i = inclination of the plane of the orbit to the ecliptic.

If the axes are rotated about Oz_2 until Ox_3 passes through the equinoctial point and Oy_3 is in longitude 90°, the co-ordinates are given in (4), where Ω is the longitude of the ascending node. These are the heliocentric ecliptic co-ordinates of the comet. The axes are then rotated about Ox_3 until Oy_3 becomes Oy_4 in the plane of the Equator in 6 h. right ascension, and Oz_4 is directed towards the north pole of the Equator, giving co-ordinates in (5), where ϵ_0 is the obliquity of the ecliptic. These are the heliocentric equatorial co-ordinates of the comet, and may be written as in (6) and in (7). In an elliptic orbit we have $x = a \cos E - ae$; and $y = b \sin E$. Hence the equations may be written as in (8).

It will be seen that the process of deriving the equations is direct and simple. No inverse trigonometrical interpolations are necessary, nor do any equations have to be solved to determine the constants, while the only reference to the trigonometrical tables is to obtain the cosines and sines of ω, i, Ω and ϵ_0. The constants can be determined to any degree of accuracy required. For very precise work the tables of Andoyer (Tables Trigonométriques, Values naturelles) are invaluable. These tables give the natural values of the sines, cosines, tangents, cotangents, secants, and cosecants to every ten seconds of arc to fifteen decimals, with first differences.

In calculating the co-ordinates it is to be noted that, by changing the sign of the sine term, one calculation gives them for both + E and — E. Another advantage arises when values of E can be used that do not involve any interpolation. In these cases the cosines and sines are taken directly from the tables, and with a calculating-machine it is quicker to perform the two multiplications than it is to add E to a constant angle involving usually seconds and decimals, to interpolate for the angle to seconds and decimals, and to perform one multiplication. For a search ephemeris, and for approximate work generally, it is not necessary to use a large number of decimals; in many cases four, and in some cases three, decimals are sufficient, and for the determination of the right ascension and declination graphical processes are very rapid, and are often accurate enough.

For those who prefer to use the equations (A) it is easier and more direct to derive them from equations (8) than it is to solve the equations given in the astronomical notes for August, 1921,* and at the beginning of this note, for by this method it is not necessary to determine all the constants A, B, C, a, b, c, &c. It is only necessary to use the relations $\lambda_x \sin L_a = a P_x$, $\lambda_x \cos L_x = -b Py$, and $v_x = -ae P_x$ to obtain the constants required.

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* This *Journal*, vol. 4, No. 4, p. 191.

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NATURAL-HISTORY NOTES.

The Paremata Whale, by W. R. B. Oliver, F.L.S., F.Z.S., Dominion Museum.

To steer safely into Porirua Harbour in a storm is a feat of which any mariner might be proud, yet it was not by this, but rather by remaining where it stranded, that the fame of the Paremata whale was achieved. Settling on the sand-flats opposite Paremata, in sheltered water, the carcase gradually drifted inshore, while prevailing westerly winds wafted a perfectly characteristic whale-odour towards the settlement. Naturally, there was some consternation among local residents. Frequent appeals were made to the Marine Department to have the specimen removed, while the nuisance was discussed by County Councils and by Parliament. Officers of the Dominion Museum visited the scene, and, finding the whale

A. C. O'Connor, photo.

The Paremata whale.

to belong to a rare species, planned to save the skeleton. In the end however, it was decided to tow the carcase to sea and let it drift. This was performed by Messrs. Perano Brothers on the 12th February, 1922, or about a fortnight after the whale came ashore.

The species to which the Paremata whale belongs is the Sei whale (*Balaenoptera borealis*). The genus *Balaenoptera* includes the rorquals, or finners, of which there are four species. *B. musculus*, the blue whale, is common in Antarctic and Arctic waters. It is rarely seen near New Zealand. The Okarita whale, the skeleton of which is in the Canterbury Museum, belongs to this species. *B. physalis*, the common finner, is more frequently seen in our seas, while *B. rostrata*, the pike whale, has been reported a few times. The Sei whale is distinguished from the other members of the genus by the small flippers, which are less than one-tenth the length of the animal; by the high falcate dorsal fin, placed well

forward, a little in advance of the last third of the body; and especially by the fine white bristles of the baleen plates.

The Paremata whale, which was an adult female, measuring 53 ft. in length, is the third of the species which has been noticed in New Zealand in recent years. In 1911 a young male, 46 ft. in length, was captured and brought into Whangamumu whaling-station. In 1915 another specimen was captured off the Bay of Islands, and was described and figured by Mr. D. G. Lillie in the *Report of the "Terra Nova" Expedition.* The species, therefore, is apparently rare in New Zealand waters, though, on account of the small amount of oil which it yields, it is not chased when other whales are to be had.

The Sei whale is found in all temperate seas. It is abundant in the North Atlantic and North Pacific Oceans, where it performs migratory movements, but somewhat irregular, as in some years it appears in very great numbers while in others it is not seen at all. In the Southern Hemisphere it has been recorded from South America and South Africa. A solitary specimen has been taken off the coast of Java.

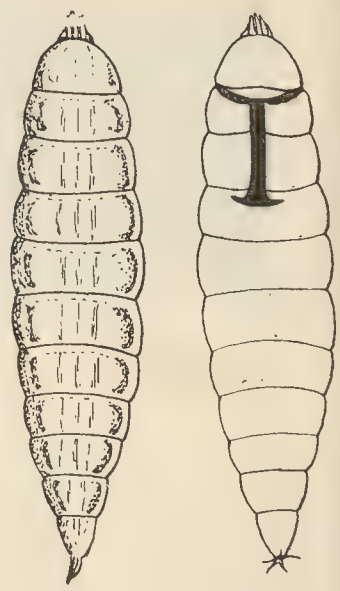
The food of the Sei whale consists of small crustacea and small fish. It appears to prefer the former, only chasing fish when crustacea are scarce.

I have to thank Mr. A. C. O'Connor for permission to use the accompanying photograph.

Biologic Notes on *Odontomyia atrovirens* Bigot (Diptera), by J. G. Myers, F.E.S.

I have previously given an account (*Journ. Sci. & Tech.*, vol. 3, p. 117, 1920), in this column of the main facts of the life-history of the Stratyomyid *Exaireta spiniger* Schiner. The following are a few notes on the similar life-history of *Odontomyia atrovirens* Bigot, another fly of the same family.

The larva is much more elongated than that of the former species, its dimensions being 17·5 mm. long, with a greatest width of 4 mm. The colour is dark brown with a paler lateral line; very little paler on the ventral surface. The surface is comparatively smooth but the segmentation very distinct. The larva was found in *Sphagnum* in the Wellington district, and was consequently reared in that material together with some damp earth. In this mixture it was in the habit of burying itself; but even at its moments of greatest activity its movements were incredibly slow. Of its feeding-habits I was unable to ascertain anything. On the 16th April, 1920, when the larva came into my possession, it appeared to be full-grown, no subsequent growth or ecdysis occurring. On the 1st September, 1920, it ceased moving; so that pupation apparently commenced about that date. This is, however, a fact difficult to verify, owing to the Stratyomyid habit of pupating in the practically unaltered larval integument. The adult fly emerged on the 28th September, 1920.



Larva. Pupa.

O. atrovirens Bigot. × 2·5.

Similar larvae occur in considerable numbers in the *Sphagnum* on the borders of the mountain-tarns of the Tararua Range.

I am indebted to Mr. B. C. Aston for the larva itself, and to Mr. David Miller for the identification of the imago.

REVIEWS AND ABSTRACTS.

The Naturalization of Animals and Plants in New Zealand, by Hon. G. M. Thomson, M.L.C., F.L.S., F.N.Z.Inst. Cambridge University Press, 1922.

The subject of naturalization of animals and plants is one of great importance not only from an economic but also from a biological standpoint. The transference of organisms from one country to another and their liberation among a different set of plants and animals is an experiment of absorbing interest. New Zealand possesses a native fauna and flora different in many respects, especially by the absence of large herbivorous animals, from that of other countries. Intentionally and unintentionally many thousands of species of exotic animals and plants have been set free in New Zealand, and, what is most fortunate, a fairly complete record of these introductions has been preserved. To the Hon. G. M. Thomson the people of New Zealand are indebted for placing before them the history of the introduction of all species of animals and plants that, so far as he can trace, have been brought to New Zealand. That he has prosecuted his search with some measure of success is evident when a count is made of the species dealt with. The numbers are—animals, 660 species, of which about 500 are naturalized; plants, 720, of which about 600 have become wild.

In addition to the author's own personal knowledge, every other source has been searched with good effect. No pains appear to have been spared in collecting information, though it involved searching the reports of acclimatization societies covering a period of sixty years.

Following a short introduction is a chapter giving the principal importations in chronological order. In the main portion of the work each species is dealt with separately and its history in New Zealand given. Most attention is paid to species of economic importance. The history of the introduction of salmon and trout is described in detail, and forms an interesting chapter in naturalization. According to the author, over a dozen species or, counting varieties, seventeen kinds of Salmonidae have been introduced into New Zealand. The success of several of these has been phenomenal; others have failed to establish themselves. In a number of streams heavily stocked with trout the native aquatic fauna has been nearly exterminated.

Of introduced mammals and birds twenty-five species of the former and twenty-four of the latter are now truly feral, but the total number of species imported was forty-eight and 130 respectively, though not all of these were liberated. Most of the smaller naturalized species of animals, including 300 of insects and seventy of worms of all kinds, have been introduced accidentally. The same remark applies to plants whose seeds have been brought among other seeds and in packing. Many plants have, of course, been introduced because of their economic value, while others have been imported for sentimental reasons.

The interaction of indigenous and introduced faunas and floras is discussed in two interesting chapters. It is pointed out that while some indigenous species have increased others have decreased. The bell-bird has increased in some districts and decreased in others. Some native insects have taken kindly to introduced plants and have increased accordingly. The common magpie-moth, for instance, has become extremely abundant wherever the introduced ragwort has become a pest. Introduced herbivorous animals such as cattle, sheep, goats, and pigs are the cause of the local extermination of several native plants, including

such species as the whau, Chatham Island forget-me-not, Cook's scurvy-grass, and king fern. The author expresses the opinion, held by all botanists in New Zealand, that the native vegetation can always hold its own against the introduced. Statements to the opposite effect have been made by such writers as Darwin and Wallace, but only on second-hand information.

Regarding the question of changes in the introduced fauna since naturalization, it is stated that there has been no definite permanent change in any introduced species.

The concluding chapters deal with acclimatization work and legislation. Many hasty introductions, some with almost disastrous results, are noted, and these are reflected in the legislation of the day designed to control rabbit and insect pests or noxious weeds. The record is interesting as showing how animals and plants, under new conditions, become so aggressive and numerous in individuals as to constitute a menace to the community.

A rainfall map and a useful bibliography complete the work. The paper and binding are of the usual high standard of the Cambridge University Press.

W. R. B. O.

AUSTRALASIAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

WELLINGTON MEETING, JANUARY, 1923.

THE Local Council of the A.A.A.S. announces that the sixteenth meeting of the Association will be held in Wellington in January next, beginning on Tuesday, the 9th.

The proceedings will last about a week, the chief business being the reading of papers and discussions on scientific subjects. Lectures of general public interest will also be given. It is anticipated that the leading scientific men in Australasia will attend, and thus a strong impulse should be given to scientific inquiry in New Zealand. A leading feature of the Association's meeting is the opportunity it gives for presenting to the public recent advances in science and their bearing on social and industrial problems.

The scope of the Association is a wide one, embracing the following subjects: Astronomy, mathematics, physics, chemistry, pharmacy, geology, mineralogy, biology, geography, history, ethnology, anthropology, social science, statistical science, engineering, architecture, sanitary science, hygiene, mental science, education, agriculture, and veterinary science.

The Local Council is desirous of receiving from authors, as early as possible, the titles of papers which they wish to read or have presented at the meeting. These should be sent to either of the Local Honorary Secretaries, Professor C. A. Cotton, Victoria College, Wellington, or Mr. W. R. B. Oliver, Dominion Museum, Wellington.

Members and associates of the Association are entitled to attend the sectional meetings and other functions of the congress. The subscription for members, ladies or gentlemen, is £1, which entitles them to receive a copy of the report of the Association. This contains as many of the addresses and papers as funds will allow. The subscription for associates, limited to ladies and students attending lectures at a University, is 10s. Subscriptions should be sent to the Local Honorary Treasurer, Professor D. M. Y. Sommerville, Victoria College, Wellington.

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THE WHALES AND DOLPHINS OF NEW ZEALAND.

By W. R. B. OLIVER, F.L.S., F.Z.S., Dominion Museum, Wellington.

THE Cetacea include those mammals of fish-like form known commonly under the names of whales, porpoises, and dolphins. The difficulty in studying the group lies in the fact that fresh material for examination is usually limited to specimens cast ashore. Occasionally whales may be examined at a whaling-station, but only of one or two species. Museum specimens are of necessity limited to skeletons or models. It is therefore largely due to accident that whales and dolphins come under the notice of the zoologist, and it is with the object of drawing attention to the subject, so that stranded specimens may be reported, that this paper is written.

Perhaps on account of the few examples that any one individual has the opportunity to examine, the identity of stranded cetaceans is frequently mistaken. As a consequence the chance of securing a rare whale for a scientific institution is lost because the local expert pronounces it to be a "blackfish" or other vague name, or the scientist may be called many miles to view a common kind because a name that really belongs to a rare species is applied to it.

Much more knowledge about the Cetacea of our seas is urgently needed, and it is hoped that sufficient information is given in this paper to enable the species to be identified by their external characters. If any one finding a stranded cetacean were to forward a description, especially giving the characters mentioned in this paper, or a photograph, to the nearest museum, possibly a skeleton of a rare species might be procured. Any observations, descriptions, or photographs of cetaceans would be greatly appreciated by the author of this paper, who would endeavour to supply the name, or other particulars, of specimens so reported to him.

By this means, also, an amount of useful information will no doubt be accumulated.

The Cetacea naturally fall into two orders—those which have no functional teeth, but instead are provided with numerous plates of baleen, or whalebone, and those provided with teeth. Within the New Zealand area there have been observed seven species of baleen whales and twenty of toothed whales, this latter order including the dolphins and porpoises. The Cetacea, as a group, are sharply marked off from all other mammals by the fusiform shape of the body, the absence of external hind limbs, the modification of the fore limbs into flippers, the superior position of the external nasal openings, and the want of differentiation in the teeth, when present. All these characters are adaptations to an aquatic mode of life. Other distinctive characters are connected with the skeleton, which is moulded to suit the fish-like form of the body. Being air-breathers, the Cetacea must frequently rise to the surface, hence the nostrils are placed on that part of the head which first appears above the water, while the upward movement of the animal is facilitated by the powerful horizontally expanded tail. A whale, on rising to blow, often begins to discharge the air from its lungs before the blowholes are quite above the surface of the water; hence results the watery spout, part of the effect being due to the condensation of the hot air on reaching the cooler atmosphere. As in fishes, the teeth, when present, are of one kind, as animals taking their food in water have no use for teeth adapted for masticating. There is thus no differentiation into incisors, or cutting-teeth, and molars, or grinding-teeth. Whales, like fishes, of necessity simply gulp their food.

The whalebone whales live on very small marine animals, such as crustacea and certain pelagic molluscs known as pteropods. Taking a shoal into its capacious mouth, the whale raises its tongue and thus forces the water out through plates of baleen, which act like a sieve. The animals are then swallowed. The arrangement of the plates which makes such an effective sieve is as follows: Each plate is in the form of a right-angled triangle, with the sides usually much longer than the base. There are stiff bristles on the longest side. The plates are arranged all round the upper jaw, close together and with their sides parallel to each other, with the bristly edges inside. They form a semicircular curtain, as it were, to the mouth.

The following synopsis will help to identify the New Zealand species of whales and dolphins:—

Order MYSTICOCETI.—Mouth furnished with baleen; no teeth.
- Family BALAENIDAE.—No grooves on throat.
  - *Balaena.*—No dorsal fin.
  - *Neobalaena.*—A small dorsal fin present.
- Family BALAENOPTERIDAE.—Throat with numerous grooves.
  - *Megaptera.*—Flippers more than one-fourth the length of the animal.
  - *Balaenoptera.*—Flippers less than one-sixth the length of the animal.
    - *B. musculus.*—Dorsal fin triangular, at last fourth of body; colour of whale bluish-grey, baleen black.
    - *B. physalis.*—Dorsal fin triangular, at last fourth of body; colour of whale slate above, white below, baleen bluish-black.
    - *B. borealis.*—Dorsal fin falcate, at last third of body; no white band on flippers.
    - *B. acutorostrata.*—Dorsal fin falcate, at last third of body; a white band across the flippers.

Order ODONTOCETI.—Teeth always present.

Family PHYSETERIDAE.—Teeth in lower jaw only, more than ten pairs; head truncate.

Physeter.—Teeth 20–25 pairs; no dorsal fin.

Kogia.—Teeth 12–14 pairs; a dorsal fin present.

Family ZIPHIIDAE.—Teeth in lower jaw only, 1 or 2 pairs; head beaked; throat with few grooves.

Berardius.—Teeth 2 pairs. (A specimen in the Dominion Museum has only 1 pair of teeth.)

Mesoplodon.—Teeth 1 pair, near middle of jaw, or, if near apex, triangular.

M. hectori.—Teeth terminal, triangular.

M. grayi.—Teeth triangular, in front of hinder end of symphysis.

M. bowdoini.—Teeth large, behind symphysis.

M. layardi.—Teeth strap-shaped (triangular when young), curved, in front of hinder end of symphysis.

Ziphius.—Teeth 1 pair, conical, at apex of mandible.

Family DELPHINIDAE.—Teeth in both jaws (except *Grampus*); throat not grooved.

Grampus—Teeth 3–7 pairs, in lower jaw only.

Pseudorca.—Teeth 8–10 pairs, large; dorsal fin falcate.

Globicephala.—Teeth 8–10 pairs, small; dorsal fin low; flippers long and pointed.

Orcinus.—Teeth 10–13 pairs, large; dorsal fin high, erect.

Tursiops.—Teeth 20–23 pairs, smooth.

Steno.—Teeth 20–27 pairs, with furrowed crowns.

Cephalorhynchus.—Teeth 30–32 pairs; dorsal fin rounded.

Lagenorhynchus.—Teeth 30–32 pairs; dorsal fin falcate.

Lissodelphis.—Teeth 44 pairs; no dorsal fin.

Stenella.—Teeth 38–46 pairs; palate not grooved.

S. pseudodelphis.—Teeth 38–42 pairs.

S. euphrosyne.—Teeth 44–46 pairs.

Delphinus.—Teeth 45–50 pairs; palate with deep lateral grooves.

FIG. 1.—Right Whale.

The right whale (*Balaena australis*) is to be distinguished from all other baleen whales by the absence of a dorsal fin, the large head (about a fourth the length of the animal), and the long narrow plates of baleen. The usual size of the baleen plates at the side of the mouth is length 6 ft., breadth at base 6 in. Colour of whale entirely black. There is a skeleton of the right whale in the Otago University Museum, Dunedin.

Right whales were formerly abundant in the seas surrounding New Zealand, but are now seldom seen. They are commercially the most valuable of whales, on account of the large amount of oil and baleen, or whalebone, which they produce. They were ruthlessly hunted by whalers less than a century ago, and by the methods employed more whales were killed and lost than were secured, and, as hundreds were killed every year, they rapidly diminished in numbers, until the hunting of them no longer repaid the sending of ships on long whaling voyages. During the months of May, June, and July the females came into bays to give birth to their young, and here, if sighted by the whalers, both were destroyed. No wonder the species is now nearly extinct! A few are even now

occasionally taken off our coasts, but not regularly, as some years none are seen.

The pygmy right whale (*Neobalaena marginata*) differs from the right whale in having a dorsal fin and in its much smaller size, 20 ft. being about its maximum length. The baleen plates are long and narrow like those of its congener. Specimens in the Dominion Museum measure 28 in. in length by $3\frac{1}{2}$ in. in breadth at the base. The colour is yellow with a black outer edge. The skeleton of this whale is very peculiar, and in some respects differs from all other cetaceans. In having 17 pairs of ribs it has more than any other living species of whale. The first rib is articulated with the second dorsal vertebra, a condition unknown elsewhere among mammals. The ribs are very broad, and join the vertebral processes at almost right angles. Skeletons of this species are in the Dominion Museum.

A very few specimens of the pygmy right whale have been stranded on the coast. It is very desirable to learn more about its external features and internal structure. No sketch has as yet been published of its appearance when alive. Besides our own seas, the pygmy right whale is known from South and Western Australia.

FIG. 2.—Humpback.

The humpback (*Megaptera nodosa*) is quite the most common of whales inhabiting the New Zealand seas: indeed, it is found plentifully in all portions of the world. It is an ungainly animal, and may at once be recognized by the long flippers, more than a fourth the total length. The dorsal fin is not very prominent, more of a hump, hence the name "humpback"; and there are numerous plaits, usually about 26 on the under-surface. Large nodules mark the lower lip, front edge of flippers, and end of the flukes. In colour this species shows considerable variation in the relative proportions of the white of the under-surface and the black of the back. The flippers are mostly white. Humpback whales attain a length of about 50 ft., the flipper reaching about 14 ft. In the skeleton the scapula differs from that of all other whales in the absence of any marked acrominon or coracoid process. No skeletons of this whale are preserved in our museums.

Whaling-stations for hunting humpbacks are now established at Whangamumu, near the Bay of Islands; Tory Channel, in the Marlborough Sounds district; and Kaikoura. Altogether about ninety whales are captured each season. Humpback whales perform regular migrations. Spending the summer in Antarctic waters, they reach our coasts on their northward trek during June, July, and August. They go north at least as far as the Kermadecs, and bring forth their young while in subtropical seas. Then the southward movement begins, and a second season for whalers, in the north of New Zealand at any rate, occurs during October and November. The migrating school must be a long one, as two or three months are

occupied on each visit north and south. It will appear also, by what has been said, that the greater portion of the year is spent in the cold waters to the south of New Zealand.

FIG. 3.—Blue Whale.

The blue whale (*Balaenoptera musculus*) is the first of the four species of rorquals, or finners, to be mentioned. It is the largest species of whale, and, indeed, of all animals, living and extinct. The now famous Okarito whale, the skeleton of which is in the Canterbury Museum, measured 87 ft. in total length, and, sundry statements notwithstanding, no bigger animal than this has actually been measured. The blue whale may be distinguished by the following assemblage of characters: Dorsal fin at commencement of last fourth of body, triangular, low; flippers one-seventh of total length; colour of whale mottled dark-bluish-grey all over, of the baleen plates and bristles entirely black; throat-plaits numerous; number of vertebrae, 64.

Abundant in Arctic and Antarctic seas, the blue whale is seldom seen in warm waters. Only two authentic records of its occurrence in New Zealand are known. One is the Okarito whale above mentioned; the other is a specimen captured off the Bay of Islands, and recorded by Mr. Lillie, of the "Terra Nova" Expedition.

FIG. 4.—Common Finner.

The common finner (*Balaenoptera physalis*) may be thus defined: Dorsal fin triangular, low, at commencement of last fourth of body; colour of body grey-slate above, white below, of baleen plates and bristles dark-bluish-black; throat-plaits numerous; vertebrae 62. Length, up to 70 ft. There are skeletons in the Dominion and Otago Museums.

This species of rorqual is found in all seas, and is occasionally stranded on our shores.

FIG. 5.—Sei Whale.

The Sei whale (*Balaenoptera borealis*) has a falcate dorsal fin situated at the commencement of the last third of the body. Colour of body above bluish-black with oblong light spots, below white; of baleen, black with

white bristles. The baleen plates are short, and the bristles differ from those of other rorquals in their fine silky appearance. The flipper is small, only one-eleventh of the total length of the body. Throat-plaits numerous; vertebrae 54–57. Average length of adult specimen, 53 ft. No skeleton is to be found in any New Zealand museum.

Although frequent in the North Temperate Zone, and possibly so in the Southern Hemisphere, only three instances of this species have been recorded for New Zealand. Two were taken off the Bay of Islands; the third was the Paremata whale, described on a previous page of this *Journal.*

FIG. 6.—Pike Whale.

The pike whale (*Balaenoptera acutorostrata*) is the smallest of the rorquals, reaching a length of 33 ft. only. Like the Sei whale, it possesses a falcate dorsal fin situated at the commencement of the last third of the body. Flippers one-eighth of total length. Throat-plaits present; vertebrae 48. Colour of body greyish-black above, white below. There is a band of white across each flipper. Skeletons are preserved in the Dominion and Canterbury Museums.

A few specimens only of this whale, which is widely distributed, have been stranded on our coasts.

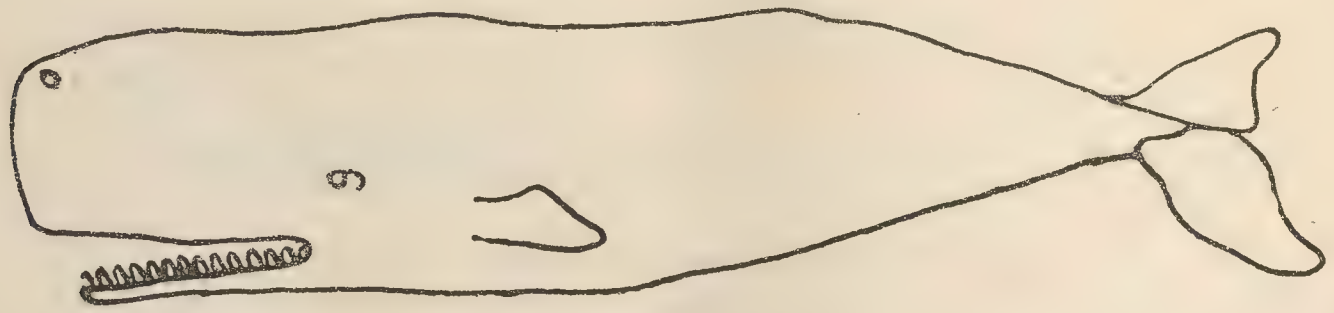


FIG. 7.—Sperm Whale.

The sperm whale (*Physeter macrocephalus*) is easily distinguished by its huge truncate head, which is about a third the total length of the animal. The blowhole is single and on the left side. Dorsal fin represented by a few humps only. Teeth large, conical, 22 or 23 on each side of the lower jaw. In this whale, as in the next species, the skull is quite asymmetrical. There are no skeletons in any New Zealand museum.

The sperm whale prefers warm waters, and is found singly or in schools throughout the tropics. Like the right whale, its numbers have been considerably reduced by whalers. It does not usually come near shore, hence its occurrence on our coasts is a rare event. However, when it does come ashore a whole school of twenty or more is sometimes stranded. This has twice happened on the Kaipara coast during the past two decades. Possibly these animals trust to a leader, and if he accidentally gets stranded the result is disaster for the whole herd.

Spermaceti is obtained from the huge snout of the sperm whale. Another valuable product, ambergris, comes from the intestines of morbid

individuals, and is occasionally washed ashore. Ambergris is a greasy substance, hardening a little on exposure. It is used in perfumery, and at one time commanded a high price.

FIG. 8.—Pygmy Sperm Whale.

The pygmy sperm whale (*Kogia breviceps*) agrees with its huge cousin in having teeth in the lower jaw only, and in the asymmetrical skull. Functional teeth, a pair only, have been recorded in the upper jaw of this species, but this appears to be quite unusual. There are 13 or 14 pairs of teeth in each ramus of the mandible; they are small and pointed, the rear ones directed backwards. The pygmy sperm whale is black with a little greyish pink on the under-surface; it has a falcate dorsal fin, and reaches a length of about 10 ft. Skeletons are preserved in the Wanganui, Dominion, and Canterbury Museums. There are also mounted skins in the Wanganui and Canterbury Museums.

The pygmy sperm whale is occasionally cast up on our coasts. During the last forty years about twelve examples have been recorded.

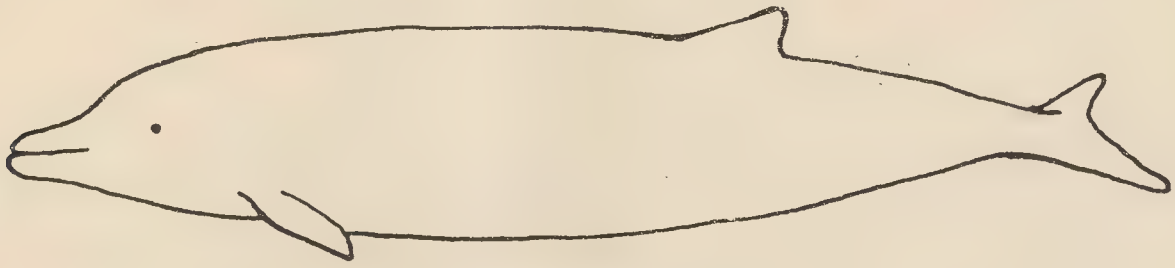


FIG. 9.—Porpoise Whale.

The porpoise whale (*Berardius arnouxi*) is a large beaked whale separated from its allies by the possession of two pairs of teeth in the lower jaw, but, like all the whales of the family Ziphiidae, functional teeth are not present in the upper jaw. A skull in the Dominion Museum has only one pair of teeth, but this condition must be considered abnormal. There is a triangular dorsal fin placed well back. The skull, unlike other members of the family, is symmetrical. This is the largest species of beaked whale, attaining a length of 32 ft. Skeletons are exhibited in the Wanganui, Dominion, and Canterbury Museums.

About ten examples of this whale have been recorded from New Zealand; elsewhere a specimen has been taken in the Rio Plata, in the Argentine. The drawing given above is a composite one, and perhaps inaccurate. It is very desirable that information be obtained as to the external appearance as well as the internal structure of this whale.

The New Zealand beaked whale (*Mesoplodon hectori*) is known only from a skull in the British Museum and a skeleton in the United States National Museum, Washington, but of the latter no description has been published. Both specimens were obtained in New Zealand. As a species it is separated from its allies by having a single pair of flat triangular teeth placed at the extremity of the lower jaw.

The southern beaked whale (*Mesoplodon grayi*) is distinguished by its pair of triangular flat teeth being situated just in front of the hinder end of the symphysis of the mandible. There is a row of small teeth on each side of the upper jaw, but they are embedded in the gum and therefore apparently of no use to the animal. As in the other beaked whales, there is a dorsal fin. The adult reaches a length of nearly 20 ft. Skeletons may be seen in the Dominion and Canterbury Museums.

The southern beaked whale has been frequently cast ashore at the Chatham Islands, less commonly on the New Zealand coast, and has been recorded from New South Wales, South Australia, and Patagonia. Very little is known of its external features or internal organization.

The sabre-toothed whale (*Mesoplodon bowdoini*) is known from two skeletons. One is in the Dominion Museum; the other, from a specimen stranded on the beach at New Brighton, New Zealand, is in the American Museum of Natural History, New York. Its distinguishing feature is a pair of very large triangular teeth situated behind the mandibular symphysis, which is short. Nothing is known of its external appearance, or, indeed, of any part of it other than the skeleton.

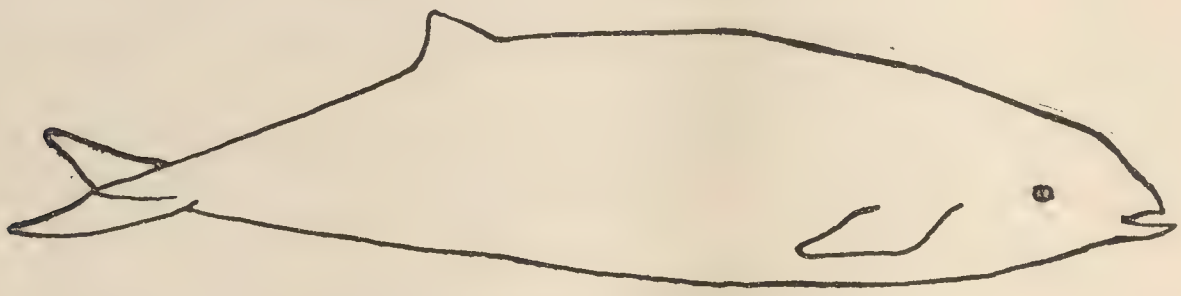


FIG. 10.—Goose-beak Whale.

The goose-beak whale (*Ziphius cavirostris*) has a short beak with the lower jaw slightly longer than the upper and turned up a little at the tip. There is a single pair of conical teeth at the extremity of the mandible. A young animal taken on the coast of New Zealand was described as purplish-black above, brown on the sides, and white below except towards the tail, where it was brown. On the throat were three grooves on each side. This species has a small triangular dorsal fin, and attains a length of 26 ft. Skeletons are exhibited in the Otago and Canterbury Museums.

The goose-beak whale is found in all seas. It appears to go about singly, or a few together.

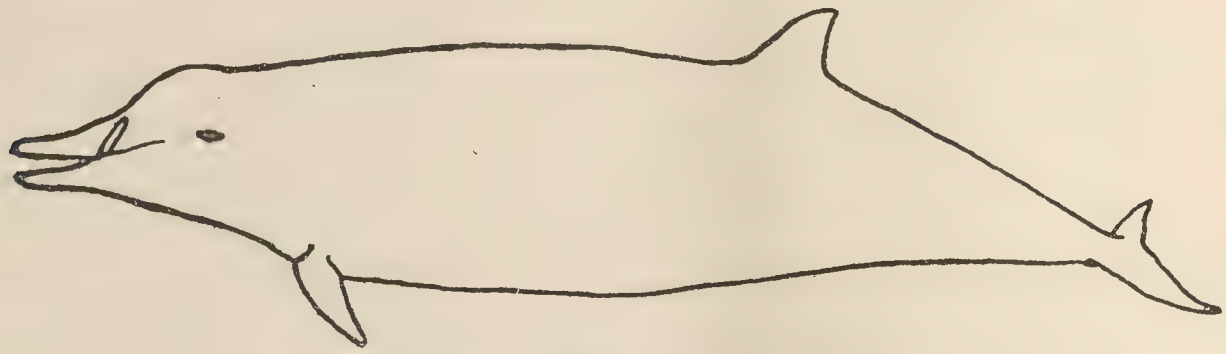


FIG. 11.—Sharp-toothed Whale.

The strap-toothed whale (*Mesoplodon layardi*) is, at least when adult, at once recognized by the two long strap-shaped teeth which, originating from the mandible in front of the hinder end of the symphysis, grow upwards and backwards, eventually curving round the upper jaw and preventing the mouth from being opened beyond a certain distance.

When young these teeth are triangular, and it is then not easy to distinguish this species from the southern beaked whale. The inward curve of the teeth, however, will indicate that the specimen belongs to the present species. The presence of a beak, dorsal fin, and outward bulge in the centre of the tail are characters of all the ziphiid whales whose external features are known. Thanks to the prompt action of the Curator of the Canterbury Museum when a specimen was stranded in Lyttelton Harbour, the outward appearance of the strap-toothed whale is known. A half model of this species and a skeleton of another are in the Canterbury Museum. In the Dominion Museum there is the skeleton of a young individual with triangular incurved teeth.

The strap-toothed whale has been several times cast upon our coast. Beyond New Zealand it has been recorded from New South Wales, South Australia, Queensland, Cape Colony, and the Falkland Islands.

FIG. 12.—Risso's Dolphin.

Risso's dolphin (*Grampus griseus*) is the first of the dolphin family to be mentioned. Its distinguishing characters are: No teeth in the upper jaw, 3 to 7 pairs in the lower jaw near the extremity; and a high triangular fin. The colour is usually grey, varying to black on the fins and tail, and to white on the under-surface. The body also is usually marked with spots and lines quite irregularly disposed. Adult individuals reach a length of 13 ft.

Risso's dolphin is a solitary animal, found in most seas. Its claim to be included in the fauna of New Zealand is based on a mandible in the Dominion Museum, and on the former occurrence near the entrance to Pelorus Sound of the famous "Pelorus Jack." This animal was accustomed regularly to play about the bows of passing steamers, and was protected by an Order in Council. Its fate is unknown, it having been last seen in 1912.

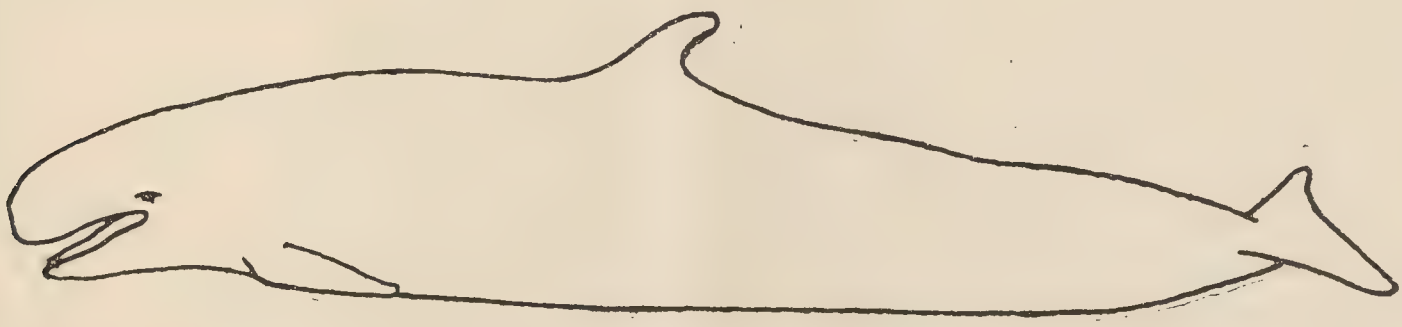


FIG. 13.—Tasmanian Blackfish.

The Tasmanian blackfish (*Pseudorca crassidens*) is, at sight, not easily distinguished from the following species. It has usually fewer teeth, 8 instead of 9 or 10, and they are much larger, being nearly as large as

those of the killer. The dorsal fin is small and falcate. The animal is entirely black in colour. There is a skeleton in the Dominion Museum, but it was imported from Tasmania.

This dolphin, like the common blackfish, goes about in large schools. One such school was stranded at the Chatham Islands about 1907. It is desirable to learn more about the external appearance of this species.

FIG. 14.—Blackfish.

The blackfish (*Globicephala melaena*) possesses 9 to 12 pairs of teeth, not nearly so large as those of the killer. The dorsal fin is low, the flippers long and pointed, and the head truncate. The colour is entirely black or with a little white on the under-surface. There are skeletons in the Dominion, Canterbury, and Otago Museums.

This species is found in all seas, frequently in immense schools. Should the leaders get stranded the whole herd usually follows suit. Unfortunately, the name "blackfish" is applied to more than one species. Reports of its occurrence, therefore, are not to be identified with this species unless accompanied by further description.

FIG. 15.—Killer Whale.

The killer (*Orcinus orca*) may be defined as follows: Dorsal fin high, erect; snout rounded; flippers large and very broad; teeth 10 to 13 pairs, large, about 1 in. in diameter; colour of animal black above, white below, and with one or more white patches on the upper surface. The killer is the largest member of the dolphin family, reaching a length of 23 ft. A skeleton is preserved in the Dominion Museum.

Killers are found in all seas. They are specially abundant in the Antarctic, where they go about in small packs hunting seals and penguins. Their ferocity is notorious. They will attack the largest of whales, and will even make an attempt on man himself should he venture too near on the ice. They may be seen off the New Zealand coast, especially in the vicinity of Cook Strait.

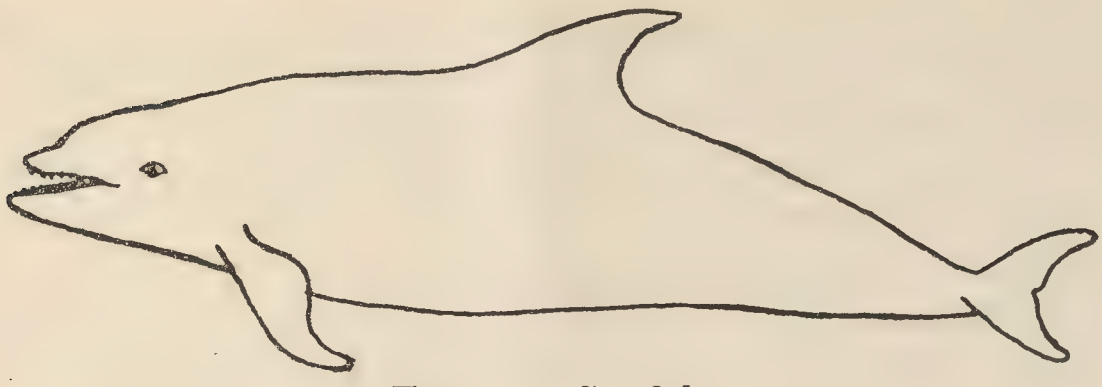


FIG. 16.—Cowfish.

The cowfish (*Tursiops truncatus*) is a large dolphin occasionally seen off the coast of the South Island, and entering the sounds in the south-west. It has a distinct but short beak, a high falcate dorsal fin, and 22 or 23 pairs of teeth. The colour is leaden above, white below, and the animal reaches a length of 10 ft. or 11 ft. Skeletons are exhibited in the Wanganui, Dominion, Canterbury, and Otago Museums.

The cowfish has been recorded from such distant parts as the North Atlantic, Indian, and Pacific Oceans.

FIG. 17.—Rugose-toothed Dolphin.

The rugose-toothed dolphin (*Steno rostratus*) is included here on the evidence of a skeleton, said to come from New Zealand, in the United States National Museum, Washington, but it has not yet been described. This dolphin has 20 to 27 pairs of teeth, which have furrowed surfaces to their crowns. There is a distinct beak and a falcate dorsal fin. The colour is purplish-black above, sides with yellowish-white spots, under-surface white tinged with rose.

The rugose-toothed dolphin is found in the Atlantic and Indian Oceans. It is very desirable that another specimen should be obtained so as to confirm the New Zealand locality. Although not hitherto recorded from the Pacific, it is not improbable that it is found in our seas.

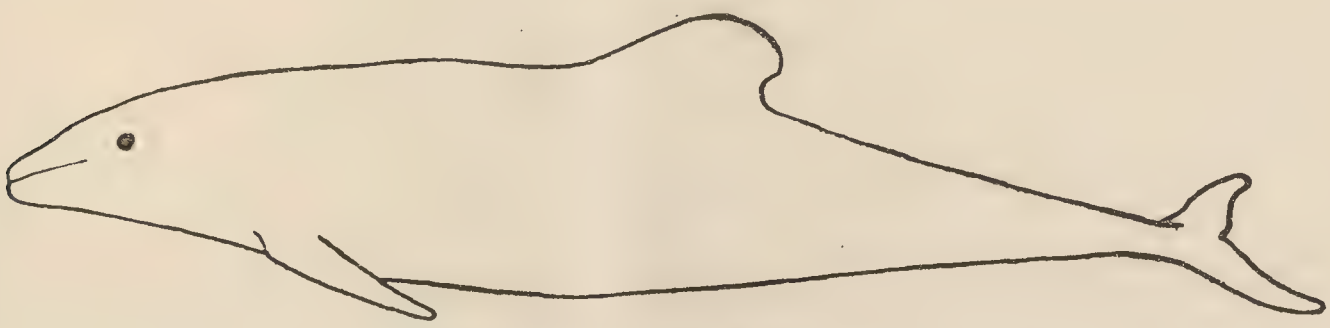


FIG. 18.—Common Porpoise.

The common porpoise (*Cephalorhynchus hectori*) may be readily recognized by its rounded dorsal fin. The beak is slightly marked, and

there are 30 to 32 pairs of small pointed teeth. In colour this porpoise is black above and white below, with the upper portion of the snout grey. The black meets below between the flippers, and on each flank a band of white extends obliquely upwards. About 6 ft. is the usual length of the common porpoise. A conspicuous feature of the skull is that the pterygoids, which are convolute bones at the back of the palate, are widely separated. There are skeletons in the Wanganui, Canterbury, and Otago Museums. A half model is exhibited in the Otago Museum, and a stuffed skin in the Wanganui Museum. The accompanying drawing is based on this specimen.

This is the common coastal porpoise seen in small schools all round our shores. It frequently meets, and accompanies for some distance, passing vessels. It is not found outside the New Zealand area.

FIG. 19.—Dusky Dolphin.

The dusky dolphin (*Lagenorhynchus obscurus*) is perhaps as plentiful round the coast of New Zealand as the common porpoise. It can be distinguished from it by the falcate dorsal fin and the more pointed snout. It is black above and white below, with an oblique white band on the flanks. There are 30 to 32 pairs of small pointed teeth, and the pterygoid bones are in contact along their inner margins. This dolphin reaches a length of between 5 ft. and 6 ft. There are skeletons in the Wanganui and Dominion Museums, and a cast in the Canterbury Museum.

The dusky dolphin is apparently widely distributed in the Southern Ocean, it having been recorded from the Cape seas and as far south as latitude 58°.

FIG. 20.—Right-whale Porpoise.

The right-whale porpoise (*Lissodelphis peroni*) can be at once recognized by the absence of a dorsal fin. It possesses a distinct beak, and about 44 pairs of small pointed teeth. The colouring is distinctive: the back is black, and this colour is sharply marked off from the under-parts, which are white, the line between the two passing above the tail, flippers, and snout.

The inclusion of this species in our fauna rests on the observation of Mr. D. G. Lillie, the Biologist of the "Terra Nova" Expedition, who sighted specimens off the coast of Otago. It has been recorded from Tasmania and Chile, and thus appears to have a wide range in the Southern Ocean.

The narrow-beaked dolphin (*Stenella pseudodelphis*) is included in our fauna on the evidence of a skull in the Dominion Museum. The teeth of this species number 38 to 42 pairs, and there is a falcate dorsal fin. The colour is described as dark above and grey below.

The narrow-beaked dolphin has been recorded from the Atlantic and Indian Oceans, but there is some doubt as to whether these records refer to the same species, or whether other so-called species are really distinct. A good description of the exterior and skeleton of the same individual is urgently needed.

FIG. 21.—Euphrosyne Dolphin.

The Euphrosyne dolphin (*Stenella euphrosyne*) is, like the last species, included in the list of New Zealand cetaceans on the evidence of a single skull in the Dominion Museum. This is a larger species than the last, attaining a length of 8 ft., and it possesses 45 pairs of teeth. There is a high falcate dorsal fin. The colour is black above, white below, with an oblique white band on the flanks.

This species has a wide range, the limits of which are uncertain. As in the last species, a good description of the exterior and skeleton of the same individual is much to be desired.

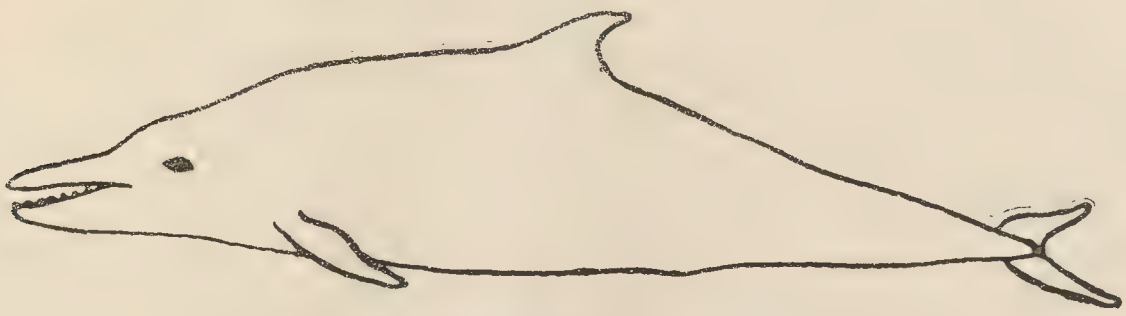


FIG. 22.—Common Dolphin.

The common dolphin (*Delphinus delphis*) has a well-marked beak and a high falcate dorsal fin. There are 45 to 50 pairs of small pointed teeth, and on each side of the palate is a deep longitudinal groove. There is considerable variation in the colouring of the dolphin. The upper surface is black, the under-surface white, but on the sides are various greyish and greenish bands. The species attains a length of between 7 ft. and 8 ft. There are skeletons in the Dominion and Canterbury Museums.

The dolphin appears to be fairly common in all seas.

COMMUNITY-SINGING AND FOLK-SONG.

By JOHANNES C. ANDERSEN, Librarian, Alexander Turnbull Library, Wellington.

COMMUNITY-SINGING as now in vogue in Wellington and other places is, of course, no new thing. A new thing gains ground very slowly, spreading from some vigorous centre; and the almost immediate popularity of the present community-singing shows that those who now take part in it with such enthusiasm already had the liking for it and the understanding of it in their hearts.

A very few generations ago this singing was common enough: the writer remembers well the frequent gatherings of friends in his parents' house—gatherings that invariably ended in singing. There was no accompaniment. The company sat on one side of the room, and all would join in song after song. There would be an occasional solo with chorus, but more often all joined in singing both solo and chorus, the latter being perhaps harmonized.

There was no question of trained voices, though there were trained voices among them, and some of them very fine. The song was the attraction; and whilst a fine voice was admired, its presence did not prevent the poorest voice from entering heartily at will. The writer particularly remembers one of the company whose singing proved him to be quite tone-deaf, yet his enjoyment was as keen as that of the others. More than once he has heard this singer say, "Do you remember such-and-such a song?" and he would do his best to hum a few bars. The others, though quite unable to recognize the melody, would catch the song from the rhythm or the words, and it would at once be sung.

The writer was in those days surprised at the extensive repertoire of those uncultured singers; but he knows now that it is said that in one part of Jutland, famous for its singing, the repertoire is so extensive that there is no need to sing the same song twice in a year.

In the Church there has always been singing by large bodies of people: it began in the open-air theatres of the Greeks, or, at any rate, it is then first recorded, and it obtains in the present day in the singing of the hymns and the psalms. It is impossible to say if the first community-singing were religious or secular; but there is no doubt that the present singing is a revival, as there is no doubt that the religious singing has been continuous. The Church always recognized the power of the secular song, and kept in touch with it by adapting secular songs, or adopting secular tunes. Both adaption and adoption are common with the Salvation Army, a comparatively recent body, whose success has been due largely to the community-spirit shown in its gatherings.

Before music became an art there was much more melodic freedom than there is now. A suggestion of what European song may have been before the introduction of harmony and a fixed notation, may be gathered from the Maori singing of to-day. In Maori music there is apparently no definite scale; a singer composing a melody, words and melody being

composed together, uses such intervals as please his individual ear, there being not only semitones, but quarter-tones and other fractions. A person learning another's song learns it tone for tone as it was sung by the composer, and it is the extreme diversity of tones within a narrow compass that gives Maori music its monotonous or elusive character to European ears.

When music became an art, and harmony was introduced, there was an averaging-up of tones, until the scales were fixed in their present form—the original diversity being shown in the different scales adopted by different peoples. This completely changed the melodic character of the old songs, and the oldest recorded melody is no doubt very different from the melody that was known before its permanent record was possible.

There was community-singing, or singing in mass, however, even when the melodic outlines were in the quite indefinite stage—indefinite, that is, to modern ears—as is suggested by the fact that the Maori people sing their strange *waiata* in mass as well as solo.

The defining of the intervals, and the assigning of definite time-values to the notes, no doubt made music easier to the average; and whilst the introduction of mean temperament gave a tremendous impetus to musical development, it destroyed a great deal of characteristic melodic variety. In time, too, from the simple ballad, dealing with heroic events or tragic incidents and the like, and the folk-song, dealing with the lives and emotions of the people, evolved the more elaborate art-song—the song in which the accompanying harmonies were as important as, and often became more important than, the words themselves. The latter is the case in much opera music and oratorio, where the torturing of words and phrases to brilliant melodic shapes is often quite fantastic. True song is merely emotional speech, and does not depart very far from speech-tunes. In the Maori song the melody floats chiefly on the best note of the singer's compass, rising or falling some two tones above or below.

It was where this elaboration of song developed most freely that community-singing fell into most disuse, or was indulged in only by what is thought of as the unmusical section of the community. In the simpler art-songs the treble of the accompaniment is the melody; the harmonizing follows the melodic form of the other parts; often, as in many hymns, the other parts have no melodic form, but are mere harmonies of the treble melody. This is the reason why a great number of simple art-songs, such as those of Denmark, sound so very like hymns, and incline to become monotonous to people accustomed to more elaborate productions.

How completely the accompaniment may be a thing apart from the melody is shown in a song like Schubert's "Slumber-song"—*Soft sighs the wood, the stream sings clear.* Here, as in many other of this composer's songs, the accompaniment is a piece in itself, beautiful without the words and melody of the song. This cannot be said of the great mass of vamp accompaniment. There is intense pleasure in listening to the floating of the melody of this "Slumber-song" on its accompaniment, and its blending with that accompaniment—far more than is derived from the melody alone. Again, in his dramatic song "The Wraith," Schubert has made the accompaniment little more than a series of strangely modulated chords, which produce a weird effect when heard apart from the declamatory song—an effect much accentuated, of course, when the words and their melody are added.

Schubert has many perfect examples of art-song, and no doubt art-song is song in its highest musical development; but it is song for the solo singer, not for communal singing. Because, too, the solo singer has been given the wealth of melody and harmony that is contained in the songs of composers like Schubert, Schumann, and the like and lesser masters—melody often requiring highly trained voices to do it justice—people begin to suppose that without training they cannot sing at all—a disastrous fallacy. No one is without voice to enjoy song, even if the best be beyond him.

So simple, whilst so beautiful, however, are many of Schubert's best art-songs that they are already entering the world of folk-song. It is notable, however, that when an art-song is taken as a folk-song its accompaniment, if not simple already, is simplified. An example is Schubert's "Adieu." This song is included in a recent "popular" collection compiled and published in America—compiled on the votes of thousands of people, so that it is thoroughly representative of real folk-fancy. Schubert's accompaniment has been discarded, however, and the melody has been harmonized so as to make a four-part song, not difficult, yet beautiful; and there is no doubt the song has become a folk-song. In this collection, too, is included "Who is Sylvia?"—a song so widely popular that the charming melody seems, in our thought, to be coeval with the words.

There are many of Schubert's songs that cannot fail to become folk-songs, for the reason that the words are already favourites, and the melodies are pure and natural, and delightfully captivating. Such a song is "Hark, hark! the Lark." Others will be taken for the sheer beauty of their melody. Such are the "Slumber-song"—*Slumber, slumber, dearest, sweetest treasure*—which Gerardy helped to make known through his 'cello; "By the Sea"; "The Linden-tree."

On the other hand, a song like Beethoven's "Adelaide," supposed to be one of the greatest songs, if not the greatest song ever written, will probably not become a folk-song. The words have a false ring that will prevent their adoption; their closing sentiment is almost banal; and the splendid accompaniment, far superior to the words it accompanies, is too varied for folk-adoption, and will live chiefly for the connoisseur. His slight "Molly's Farewell," on the other hand, a simple but beautiful creation, is almost sure to be adopted.

The reason for the quotation of examples from German rather than other composers is that it was in German hands that art-song reached its summit of perfection, largely because fine musicians and fine poets co-operated in the production of song-immortals. When musicians like Beethoven, Schubert, Mendelssohn, Schumann, might be influenced by the lyrics of poets like Goethe, Heine, Schiller, what wonder that songs like "Mignon," "Thou'rt like a Lovely Flower," "Gretchen at the Spinning-wheel," sprang into being. Or what wonder that the mingling of Shakspeare and Schubert resulted in "Hark, hark! the Lark" and "Who is Sylvia?"

It is rarely that poet and musician are combined in one and the same person; our own Charles Dibdin was such a one, but he was not of master rank—"Tom Bowling" is one of his immortals. Carey was made famous by "Sally in our Alley," but his tune was discarded in favour of the one now in use. Thomas Campion was of higher rank than either of these, but his songs partook of the old-time indefiniteness of melody and rhythm,

otherwise such beautiful songs as " What if a day, or a month, or a year, crown thy delights with a thousand sweet contentings " would be far more widely known and loved than they are.

The many collections of songs appearing from time to time are an index of the general feeling for song that stirs in the human breast. On one plane we have collections like the *Colonial Songster*, published both in Australia and New Zealand ; on a higher plane, Cole's *Thousand Best Songs*. And who does not remember the popularity of the travelling singer Thatcher, who went the round of New Zealand, publishing his songs in the principal towns ?—a reincarnation of D'Urfey or Martin Parker. Then there are Ritson's collections of old English and Scottish songs ; Motherwell's collection ; Boosey's, and Baring Gould's—to mention but a few ; and the last in the writer's observation, the volume of " Heart-songs " published in New York in 1909. It is notable how each new collection includes songs created since the appearance of the preceding collection ; in the volume of " Heart-songs," besides those of Schubert mentioned, Kjerulf's " Last Night " is included ; and it is remarkable, considering the collection is of American origin, how purely British the great bulk of it is. The small song-book recently issued by the committee of the Wellington community-singers is on very much the same lines as its predecessors, differing rather in the extent of the collection than in the character of the songs ; and it might be observed that the printing of these collections gives opportunity for the introduction of at least one or two of the higher-class songs that might otherwise escape deserved immortality in the general heart.

THE MAORI METHOD OF DRILLING.

By ELSDON BEST, Dominion Museum.

With illustrations by J. MCDONALD.

A PROLONGED and painstaking inquiry has shown that the pump drill and bow drill were unknown to the Maori in pre-European days. The European form of pump drill was introduced in the early days of European settlement. Had the Maori known the pump drill in former times it would have been the free-bar drill that was used by the natives of the western Pacific. The pierced-bar form was not known in that region in olden times. It was made known in these seas by early European visitors and residents. I know grey-headed natives who know only the introduced pierced-bar pump drill, having forgotten the old *tuiri* of their fathers.

The form of drill formerly employed by the Maori was the cord drill, or thong drill, a primitive form that has puzzled some ethnographers ; in ancient days it was used in India. In this form no sliding bar whatever was employed ; the drill was controlled by means of the cords alone. This was the old native drill, the *tuiri*, *ore*, or *wairori*. The desired impetus was gained sometimes by means of stones lashed to the shaft, by means of a solid wheel or disc of wood, or by the attachment of a four-spoked wheel to the shaft. The boring-point of quartzite or some other hard stone was lashed securely to the lower end of the shaft. In order to set the apparatus going, the cords were wound round the shaft by means of

turning the latter. Holding a cord in each hand, the operator, by pulling them in a downward direction, starts the reciprocal motion that one sees in the pump and bow drills. No form of cap-piece was employed, so far as we know, to control and steady the shaft, the consequence being that the shaft did not preserve a vertical position, but wobbled a good deal. This resulted in the crater-shaped hole seen in old Maori artifacts. The course adopted was to bore from both sides, so that the holes met in the centre, with more or less precision. The boring process was accelerated

FIG. 1.—Stone-drilling by Aperahama, Koriniti, Whanganui district.

by means of using hard grit sand as a triturating agent, combined with a very small amount of water.

The illustration shows the drill in position on a block of stone. These light drills were, of course, employed in boring small articles only, for light work, such as piercing lines of holes in a flat piece of bone, in the manufacture of fish-hooks. Larger and heavier implements were used for such work as boring the hand-grip of a stone weapon. The late Mr. John White described a form of cap-piece to control the drill-shaft, but we have no evidence to show that the Maori utilized such an aid in pre-European days.

FIGS. 2, 3.—Stone-drilling by Te Rangiua and his wife Wharemutu, Urewera district.

A NEW METHOD OF PROPORTIONAL REPRESENTATION.

By Dr. J. ALLAN THOMSON, M.A., F.N.Z.Inst.

SOME time ago I had occasion, as member of a committee of the New Zealand Institute, to examine systems of proportional representation and preferential voting with a view to framing a method for electing Fellows of the Institute. This experience, together with listening to the excellent lectures of the late Mr. George Hogben, C.M.G., constitutes almost my total acquaintance with proportional representation, and I lay no claim to any deep knowledge of the subject. It is therefore with some diffidence that I put forward a new method of proportional representation, and I do so only because I believe that this new system contains features which are quite novel, and which meet some of the most serious objections urged, with reason, against the generally adopted system—viz., that with the large electorate, the quota, and the single transferable vote.

For the election of Fellows of the New Zealand Institute any system of proportional representation was found to be quite unsuitable, for the main aim of these systems is to elect parties, not persons, and the election in question was one into which parties did not enter. I was then led to digress to political elections, and to seek whether a method could not be devised by which due weight could be given both to the fair representation of parties and to the election of candidates who by their personality and character make the strongest appeal to the electors. Before discussing the relative merits and demerits of the existing system in New Zealand of "first past the post," and of the ordinarily advocated method of proportional representation, it will clear the ground to outline the new system.

For the benefit of those readers not resident in New Zealand I should explain that the country is divided into 80 electorates, 4 of which are allocated to the Maoris, leaving 76 for the European population. These 76 electorates have their boundaries altered at short periods by an Electoral Commission in such a way that the numbers of electors in each electorate are practically equal, with one important exception, known as the "county quota" giving rural electors an 18-per-cent. preference over urban electors. It is one of the objections urged against proportional representation in New Zealand that it would destroy the "country quota."

At the present time there are four political parties or groups in New Zealand, viz.: A, the Reform Party (in power); B, the United Liberal and Labour Progressive Party (the official Opposition); C, the official Labour Party (the political organ of the Alliance of Labour); and D, various independents.

The new system I describe retains the present electorates and present methods of nomination, with the exception only that candidates must register their general allegiance to one of the above parties or fall into the group of independents. Two issues are to be placed before the electors, one a purely party issue, the other purely personal.

1. Do you vote for party A, B, C, or D ?
2. Do you vote for candidates *a*, *b*, *c*, *d*, *f*, &c. ?

The number of votes cast in each electorate for the four parties is to be transmitted to the Chief Returning Officer, who shall add 18 per cent. in the case of the rural electorates so long as the country quota is to be retained, and shall prepare the grand total of votes cast for each party. The 76 seats shall then be divided amongst the four parties proportionately to these totals.

Let us suppose that the result is—Party A, 45 seats; B, 18 seats; C, 10 seats; and D, 3 seats. The returning officer for each electorate shall also transmit to the Chief Electoral Officer the percentage of the total numbers of electors on the roll that have voted for each candidate. The 45 candidates of A party having the highest percentages within that party shall then be declared elected, and similarly the 18 candidates of B party with the highest percentages within that party, and so on.

An obvious anomaly at once suggests itself. Under this method of election it will be possible for some electorates to be represented by two members each and for other electorates to have no members directly representing them. Actually this position will rarely arise, and when it does it will be in general those electorates with the highest percentages of voting that will be favoured by two members and those electorates with the lowest percentage of voting that will be penalized. This will put a premium on the exercise of the power of voting, a state of affairs that is in itself desirable. In practice the electorates without members need not suffer greatly, for the rejected candidates or their committees can agree to ask some of the members in the over-represented electorate to watch over the interests of their district in Parliament—an honour that they will probably be quite willing to accept.

If, however, it is considered too anomalous a position to have electorates without members and others with two members, each one of two slight modifications of the system may be adopted which will ensure a single member for every electorate and yet retain the advantages of the system. The first modification of the system would be that in each case where the proportion of votes gained by two candidates in any electorate apparently entitled both to be elected, the election should go to the candidate having the majority of votes over the other. This would then necessitate that the party to which the other of the two candidates belonged would be entitled to an extra seat in some other electorate. *i.e.*, if the party were entitled to n seats and the mth candidate in proportion of votes could not take his seat for the reason above, then the n^1th candidate in proportion of votes would be entitled to a seat. It seems possible, however, that difficulties might arise in the case of the last of the seats to be apportioned to the party or parties winning the smallest number of seats on the party vote. As these parties, and particularly the Independent group, are unlikely to have candidates in every electorate, and as the candidates lowest on the list in their party according to proportion of votes polled are likely to be also lower in votes polled than the candidates of other parties in their electorate who may be also eligible as members from their position in their party list, cases might possibly arise where no candidates were available to fill the seats due to the party, and the scheme of election would be imperfect.

Another modification, not at first sight apparently so reasonable as the last, would get over this difficulty. It would be for the Chief Electoral Officer to commence apportioning the seats to the parties in the inverse order of their numerical strength. If the parties were, as before, entitled to seats in the numbers A, 45; B, 18; C, 10; D, 4; he would first

apportion 4 seats to the 4 highest D candidates, then 10 to the 10 highest C candidates, and so on. The A party, being in the majority, would almost certainly have candidates for all the 45 seats apportioned to them, and in quite the majority of these the candidates would be also those who had polled most votes.

No doubt other modifications would be suggested which would solve the problem of providing each electorate with a member and yet preserving the proper proportion between the parties. The point to be emphasized is that any such is only a very minor modification of the main scheme, likely to affect only a very few seats, if any at all, in any given election, and that whatever modification is chosen the results would differ very little from the first alternative I indicate.

The present method of election in New Zealand and Great Britain by "first past the post" has two main disadvantages. The first is that owing to three-cornered contests it is possible for one party to obtain more seats than the proportion of voters in the country properly entitles it to. It has often been claimed that the majority party has a minority of votes—*e.g.*, in the case of the British Liberal majority of 1906, and the New Zealand Reform majority of 1919. We need not admit these claims as proved, for the facts that certain seats were unopposed, and that in others the majority party had no candidates, prevents an accurate estimation of the strength of the various parties in the country. An additional difficulty is presented by the personal element, for a voter supporting party A and strongly opposed to party C may vote for the candidate of party B either from a personal objection to the candidate of A, or from a belief that the candidate of B is more likely to win the seat from the candidate of C than is the candidate of his own party A. Nevertheless it must be admitted that the possibility exists of the party winning the majority of seats being in a minority in the country, and this is one of the strongest arguments in favour of proportional representation. This disadvantage of the "first past the post" system does not exist in the scheme I have put forward, as there is a straight-out party vote in every electorate.

The second disadvantage of the present method of election is that the candidate chosen for the party an elector favours may be inferior in ability, forcefulness, or moral character to the candidate of one of the other parties, and the elector is driven to make a choice between the claims of party and his private judgment as to the best man. The usual result is that the claims of party prevail, and this is one of the strongest reasons why men of inferior calibre in all parties occasionally, I dare say, often become elected members of Parliament.

This disadvantage applies with equal or even greater effect where electors are urged to vote for a "ticket," as was the case in the old New Zealand city electorates of three members, and as is necessarily the case in the ordinarily accepted system of proportional representation. It is entirely removed in the scheme I have put forward, for the elector has practically exhausted his power of supporting his party by his direct vote on the party question, and is free to vote for the candidate he considers the best man without in any way weakening his party's cause. Indeed, if he exercises his vote against the weak candidate of his own party he is really voting in the party's interest, for he is strengthening the chances of election of the stronger men of his party in other electorates, and he is voting in the country's interests by voting for the best man in his own electorate. The new scheme, therefore, will have a tendency to improve

the average calibre of members of Parliament in all parties, and this is a very strong argument in its favour.

The disadvantages urged against ordinary proportional representation are, in the words of the Right Hon. Mr. Massey, that "it fails to give those results which alone ensure stability of government, and the representation of parties by their ablest and most trusted members. Under the proportional system . . . the tendency is to substitute 'group politics' for party government, without which there can be no real parliamentary government on democratic lines. On the facts adduced it would appear that the proportional system destroys local representation, and those personal relationships between members and their constituents which are so helpful in our political life; that it weakens, if it does not destroy, majority rule, by giving minorities undue influence in the counsels of a stronger minority party; and that it plays into the hands of the strongest and most ruthless of the party machines."

In the new scheme three at least of these disadvantages are entirely removed. It does not destroy but preserves local representation and those personal relationships between members and their constituents which are so helpful in our political life. It does ensure, even better than the present method, the representation of parties by their ablest and most trusted members. It does not play into the hands of the strongest and most ruthless of the party machines, but rather the opposite. Let me elaborate this last point. The policy of the party machine is to eliminate any but the slavish followers of the party platform from the parliamentary representatives of the party. The machine tries to crush out the independents, and particularly the semi-independents. Let us consider the position of these two categories of candidates under the new scheme. The independent, the man who stands completely outside party, is not particularly favoured in the new scheme, for his chances of election are conditioned by the general dissatisfaction of the public with all parties, and in general the proportion of the total vote cast against all parties will not be great. It should at any time, however, be great enough to return much the average number of complete independents that obtains under the present system. When the independent candidate is an outstanding man likely to secure a large number of personal votes he is likely also to swing an equal number of votes in his own or other electorates to the independent group. So we may assume that the chances of the independent, if not improved by the new scheme, are at least not greatly diminished, as is the case in ordinary proportional representation.

On the other hand, the position of the semi-independent, the man who favours one party sufficiently strongly to register his candidature in its name, but who retains his freedom of voting on all but no-confidence motions, the position of such a man is greatly improved under the new scheme. Under it, as under the present system, he is unlikely to be accepted by the leader of the party as its official candidate. But whereas under the present system the party voter refrains from voting for him lest the party vote be split and the seat be lost to the party, under the new system the party vote cannot be split, and the only effect of splitting the personal vote between the official and unofficial party candidates is the danger of neither gaining a high enough percentage to be entitled to a seat, and the consequent danger of the electorate having no member. This is not nearly so serious a danger as that of losing a seat to the party, and the voter consequently will feel freer to exercise his personal prediliction. The chances of election of the semi-independent are

thus increased, and the powers of the party machine are correspondingly lessened. In these respects the new scheme has the advantage both over the present system and ordinary proportional representation.

There remains the question of whether the new scheme will tend to substitute "group politics" for party government. Democratic government on party lines is only possible where there are only two dominant parties in a country. One of these parties receives a "mandate" from the electorate to take over the reins of government, and the Cabinet that really governs for the party practically decides the party's policy on the new aspects of affairs that continually turn up, and carries on till its sins of commission or omission gradually strain the loyalty of the party electors. There is then "a swing of the pendulum" at a general election, and the other party is given a "mandate" to govern for a series of years, until it in turn has outlived its welcome. Though in smaller matters a party Government may enforce a course of action of which a minority only in the country approve, in all major matters it must reflect the will of the people, or fall. In this way, by the alternation of power between the two parties, each expressing at different times some aspects of the popular will, true democratic government results, and the will of the people ultimately prevails. For such a system of government it is an advantage if the party temporarily in power has a comfortable majority in Parliament and can govern strongly. If the voting-strength of the two parties is approximately equal, it is then an advantage to have an imperfect system of election which will allow first one party, and then the other, to have a parliamentary majority out of proportion to its real voting-strength. Under such circumstances any system of proportional representation will tend to produce weak government.

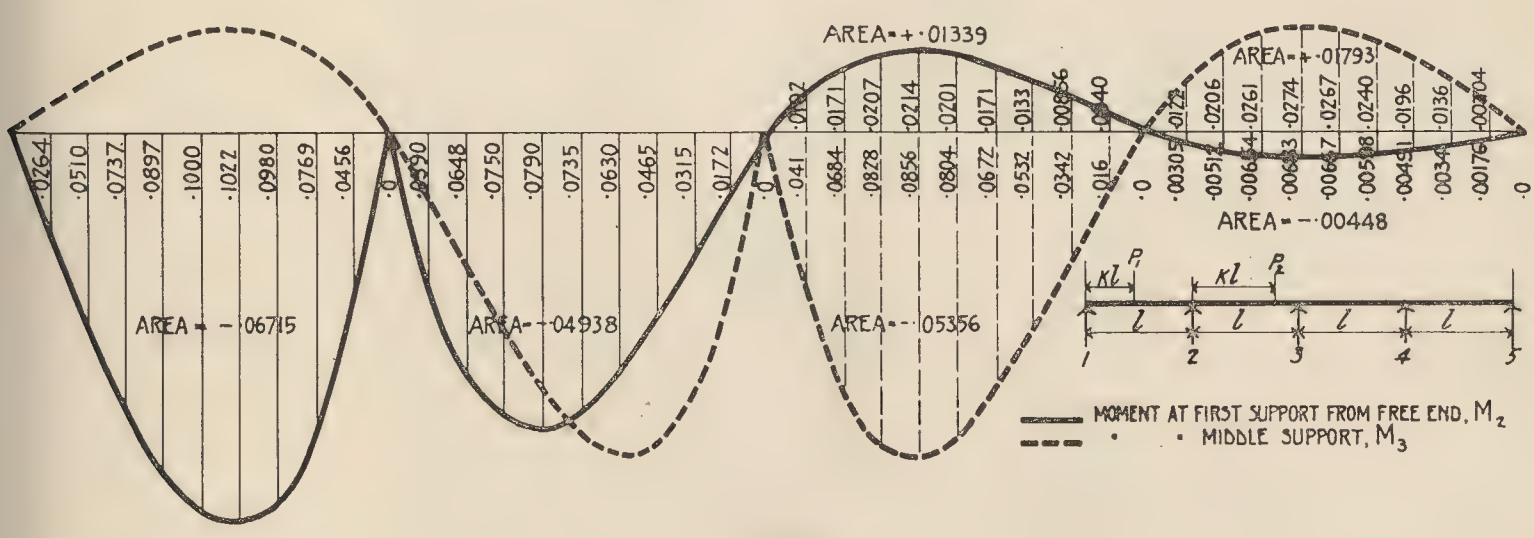
But do these conditions any longer exist in any British community? Apart from the existence of groups within the great British Liberal and Conservative parties on the important subjects of the Irish question, protection, foreign policy, and defence, Church disestablishment, and the liquor question, the steady rise of the Labour party threatens to upset entirely the two-party system of democratic government and to introduce "group politics" in its place. An imperfect system of election may stave this off temporarily, but the time must come before long when it becomes inevitable, since the Liberal and Conservative attitudes to affairs appear to be part of human nature and the political aspirations of Labour coincide with neither of these attitudes. When a Labour party becomes strong enough to render two-party government impracticable, some form of group politics becomes inevitable, and then the demand for proportional representation in some form will become too strong to be resisted.

The new scheme I have outlined has not been elaborated in its machinery aspects, such as methods of counting fractions in the proportions between the parties, by-elections, methods of purifying the rolls, conditions of recognition of new parties, &c. It would be more expensive than the present system, but much less expensive than ordinary proportional representation. I have put it forward in its present perhaps crude form mainly to provoke discussion, and not from any strong bias against the present admittedly imperfect system. I have tried to make out as favourable a case for it as possible in order to ensure for it such support as will cause its merits and demerits to be canvassed both by electoral experts and by politicians.

BENDING-MOMENTS IN CONTINUOUS BEAMS.

By W. S. GRAY, B.A., M.A.I. (Dublin), Lecturer in Civil Engineering, Auckland University College.

IN the design of continuous beams of reinforced concrete it is often necessary to solve the "equation of three moments" for the cases of three- or five-point loadings on each span. It is also required to know which bays must be loaded with the live load in order to produce the maximum moment at any given support. The method of influence lines has already been worked out for three equal spans, and it is now proposed to extend the method to the case of four equal spans. From the derived curves the moment at any support can be ascertained in a few seconds with a slide-rule, and the worst loading for any support may be obtained by mere inspection. Structures in which the live load cannot move along the span—*e.g.*, the bottoms and side walls of tanks, silos, bunkers, raft foundations, retaining-walls, &c.—can be designed more economically and accurately by using the moments derived from these curves than by using the common approximation for the bending-moment of $0{\cdot}1wl^2$.



One assumption only is made—namely, that the moments of inertia of all spans are equal. It has been shown by S. E. Thompson that the greatest possible practical variation in ordinary design gives a difference of less than 10 per cent. in the bending-moment, and under most conditions the difference is much smaller.

The general form of the "equation of three moments" is—

$$M_2 l_2 I_3 + 2M_3 (l_2 I_3 + l_3 I_2) + M_4 l_3 I_2 = - \Sigma P_2 l_1{}^2 I_3 (K_2 - K_2{}^3) - \Sigma P_3 l_3{}^2 I_2 (2K_3 - 3K_3{}^2 + K_3{}^3),$$

if all supports are on the same level.

If $l_2 = l_3 = \&c., = l$, and if $I_2 = I_3 = \&c., = I$,

then $M_2 l + 4M_3 l + M_4 l = - P_2 l^2 (K_2 - K_2{}^3) - P_3 l^2 (2K_3 - 3K_3{}^2 + K_3{}^3)$.

Take the case of four equal spans with a load P_1 at a distance equal to Kl from the free end of the left-hand span. Number the supports 1 to 5 from left to right. Then, for spans 1–2 and 2–3,

$$M_1 l + 4M_2 l + M_3 l = - P_1 l^2 (K - K^3) - 0$$
$$\therefore 4M_2 + M_3 = - P_1 l_2 (K - K^3), \text{ since } M_1 = 0.$$

Similarly, $M_2 + 4M_3 + M_4 = 0$

$$M_3 + 4M_4 = 0.$$

These equations give $M_3 = -\frac{4}{15}M_2$; $M_2 = 15M_4$; and
$$M_2 = -0{\cdot}267\,P_1 l\,(K - K^3).$$

Suppose P_1 = unit load and l = unit span, and calculate the values of M_2, M_3, and M_4 for various positions of the unit load on the span 1–2. For convenience take the tenth points of the span :—

K.	$(K - K^3)$.	M_2.	M_3.	M_4.
0·1	0·099	− 0·0264	+ 0·00704	− 0·00176
0·2	0·192	− 0·0510	+ 0·01360	− 0·00340
0·3	0·273	− 0·0737	+ 0·01960	− 0·00491
0·4	0·336	− 0·0897	+ 0·02400	− 0·00598
0·5	0·375	− 0·1000	+ 0·02670	− 0·00667
0·6	0·384	− 0·1022	+ 0·02740	− 0·00683
0·7	0·357	− 0·0980	+ 0·02610	− 0·00654
0·8	0·288	− 0·0769	+ 0·02060	− 0·00512
0·9	0·171	− 0·0456	+ 0·01220	− 0·00305

Next suppose that the only load is P_2 on the span 2–3 at a distance Kl from the left-hand end of that span. Then

$$M_1 + 4M_2 + M_3 = -0 - P_2 l\,(2K - 3K^2 + K^3)$$
$$\therefore 4M_2 + M_3 = -P_2 l\,(2K - 3K^2 + K^3).$$
Also, $$M_2 + 4M_3 + M_4 = -P_2 l\,(K - K^3)$$
$$M_3 + 4M_4 = 0.$$

As before, calculate M_2, M_3, and M_4 for $P = 1$ and $l = 1$ and for different values of K :—

K.	$(2K - 3K^2 + K^3)$.	M_4.	M_3.	M_2.
0·1	0·171	+ 0·00400	− 0·0160	− 0·03900
0·2	0·288	+ 0·00855	− 0·0342	− 0·06475
0·3	0·357	+ 0·01300	− 0·0532	− 0·07500
0·4	0·384	+ 0·01710	− 0·0672	− 0·07900
0·5	0·375	+ 0·02010	− 0·0804	− 0·07350
0·6	0·336	+ 0·02140	−0·0856	− 0·06300
0·7	0·273	+ 0·02070	− 0·0828	− 0·04650
0·8	0·192	+ 0·01710	− 0·0684	− 0·03150
0·9	0·099	+ 0·01025	− 0·0410	− 0·01725

As the beam is symmetrical about support No. 3, we have now the required data for drawing influence-line ordinates for the moments at supports Nos. 2, 3, and 4 for any concentrated load on any span. These curves can be drawn on decimally divided squared paper to suitable scales. For instance, let there be a concentrated load of W lb. at the middle of each of the four spans.

Then $M_2 = (-{\cdot}1000 - {\cdot}0735 + {\cdot}0201 - {\cdot}0067) \times W \times 30 \times 12$ in pounds
$= -{\cdot}1601\,W \times 360 = -57{\cdot}8\,W$ in pounds,

and $M_3 = (+{\cdot}0267 - {\cdot}0804 - {\cdot}0804 + {\cdot}0267)\,W \times 360$ in pounds
$= -{\cdot}1074\,W \times 360 = -38{\cdot}6\,W$ in pounds.

For uniformly distributed loads we must find the areas of the four curves, reckoning those above the horizontal axis of abscissal positive and those below negative.

For a uniform dead load over all four spans and equal to W_1 lb. per foot-run we have

$$M_2 = (-{\cdot}06715 - {\cdot}04938 + {\cdot}01339 - {\cdot}00448)\,w_1 \times l^2 = -{\cdot}10762\,w_1 l^2.$$

For a live load, w_2 lb. per foot-run, over all four spans

$$M_2 = -\cdot 10762\, w_2 l^2.$$

But if there is no live load on span 3–4, then

$$M_2 = -\cdot 10762\, (w_1 + w_2)\, l^2 - \cdot 01339\, w_2 l^2,$$

which is greater than $-\cdot 10762\,(w_1 + w_2)\, l^2$, the moment at 2 when the live load covers all four spans.

The position of moving or rolling loads to give maximum values of M is easily seen by inspection alone.

STUDY OF MARINE CURRENTS.

By the Hon. GEO. M. THOMSON, M.L.C., F.L.S., F.N.Z.Inst.

WHEN the Portobello Marine Fish-hatchery, in Otago Harbour, was opened, in 1904, one reason advanced for the selection of the southern site was that owing to the occurrence of a north-easterly current along the coast of Otago everything set free in the ocean there would almost certainly tend to go up the coast in a northerly direction. Thus lobsters, crabs, or larval fish liberated from the hatchery might be expected to appear at Akaroa or any other point to the north of Otago Heads. An interesting experiment, commenced two years ago, verifies the correctness of this theory. Glass bottles, corked, and sealed with hot pitch, have been set free in the sea off Otago Heads in batches of a dozen or so about every fortnight. Each bottle contains a printed slip stating where and when it was set free, and requesting the finder to fill in the date and locality of recovery, and place the slip in an enclosed stamped envelope addressed to the Hon. Secretary of the Hatchery Board. The bottles are so weighted as to float just to the surface of the water, and thus leave no space for wind-action.

The first lot was liberated on the 16th January, 1920, and the last at the beginning of May of this year. Of the first 438 bottles set free, fifty-one have been recovered and reported. Considering the great extent of the northern beaches, the comparatively few persons who patrol them, the long stretches of shingle against which bottles would probably be smashed, and also the extent of reef and rock formation, this recovery, amounting to $11\frac{1}{2}$ per cent., may be considered to be fairly satisfactory.

Bottles set free within three or four miles of Otago Heads are usually swept into Blueskin Bay, a few miles to the north-west; but as the distance of the liberation-point is carried farther out—to ten or twelve miles—they drift north and north-east. Five bottles found their way back into Otago Harbour, and two were picked up on the North Spit at the Heads. These were probably caught by a tidal current or local winds, and so were swept inshore. The rest were collected as follows: Longbeach and Purakanui, 10; Puketeraki, 1; Waikouaiti, 5; Shag Point, 6; Moeraki, 4; Hampden, 2; Kakanui, 2; Timaru, 2; Orari Mouth, 1; Rangitata Mouth, 1; Sumner, 1; New Brighton, 3; Kaiapoi, 2; North Canterbury, 1; Lyall Bay, Wellington, 1; Chatham Islands, 3. This last station is most interesting, and shows that there must be a strong set from south of Banks Peninsula towards the islands, because for one bottle recovered from such an out-of-the-way locality a score or more must have gone astray. It is worthy of note that no bottles have drifted to the south of Cape Saunders.

THE GEOCHEMISTRY OF THE THERMAL LAKES, NORTH ISLAND, N.Z.,

In relation to Problems bearing on the Acclimatized Salmonidae.*

By W. J. PHILLIPPS, F.L.S., F.R.G.S., Dominion Museum, and F. J. T. GRIGG, B.Sc., Dominion Laboratory.

INTRODUCTION.

IN the course of an investigation on matters relative to trout in the thermal lakes, North Island, New Zealand, it was considered advisable that some definite data be obtained regarding the content of a number of typical waters from the district, and that some endeavour be made to correlate the general water-constituents with the nature and abundance of the trout food-supply. Our efforts have been partially successful. We are unaware of any like analysis made in this manner in any part of the world, and so are unable to institute comparisons. We realize that, although the actual water-constituents are a fundamental basis of many trout-culture problems, many other extraneous influences have a definite bearing on all problems relative to the subject.

Our thanks are due to those gentlemen who have enabled us to bring this work to a successful completion. In particular we have to express our indebtedness to the following: Dr. J. S. Maclaurin, Dominion Analyst; Mr. W. Donovan, M.Sc., Assistant Dominion Analyst; Mr. T. E. Perks, B.Sc., Dominion Laboratory; and Mr. W. Hill and Mr. W. Cobeldick, Tourist Deptarment, Rotorua.

PHYSIOGRAPHY.

For purposes of comparative study the district may be divided geologically into two areas by a straight line drawn through Waiotapu in a north-westerly and south-easterly direction. That portion of the country lying to the immediate south of this line constitutes the headwaters of the Waikato River watershed, while the land on the north and immediate north-east is drained by the Kaituna and Tarawera Rivers, which flow into the Bay of Plenty. This northern area may be further divided into two sub-areas in which lie the great lakes.

Firstly, Lakes Rotorua, Rotoiti, Rotoehu, and Rotoma, which lie in a line due east and west, constitute what may be termed the Rotorua series. The Ohau Channel carries the surplus water from Lake Rotorua to Lake Rotoiti, which has an outlet at the Okere Falls by the Kaituna River. Lakes Rotoehu and Rotoma have no surface outlet, but from each there is probably a continuous underground soakage of their waters through the pumice strata to Lake Rotoiti.

Secondly, what may be termed the Tarawera series is a scattered group of lakes lying to the south of the Rotorua series. These are Lakes

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* A paper read before the Natural-history Section, Wellington Philosophical Society, 4th October, 1921.

Okareka, Tikitapu, Rotokakahi, Okataina, Tarawera, Rotomahana, and Ngahewa. Lakes Okareka and Tikitapu are probably connected underground with Lake Rotokakahi, from which the Wairoa Stream flows into Lake Tarawera. The surplus water from Lakes Okataina and Rotomahana doubtless flows underground to Lake Tarawera, which is drained by the river of that name.

This subterranean transference or soakage of water, so noticeable in this region where many of the lakes have no surface outlet, may be explained by the possible presence of a pumice strata underneath the volcanic rocks, through which the water may easily precolate on account of the majority of the stones being water-worn or broken up by volcanic action.

The Taupo series of lakes are situated at the base of the volcanic peaks of Ngauruhoe and Tongariro. Lakes Taupo and Rotoaira have each been considered here. The Waikato River enters Lake Taupo at its southern end and leaves at its northern border. Lake Rotoaira, which is surrounded by numerous cold mineral springs, is five square miles in area, and is drained by the Poutu River, which joins the Waikato. Lake Taupo, which is the largest lake in New Zealand, receives some forty streams and rivers, and is 238 square miles in area. At a short distance from where the Waikato River leaves the lake are the Huka Falls, preventing the egress of trout.

THE TROUT.

Falls or cataracts prevent the trout leaving the particular lake in which they exist, and, save in the case of the Rotorua and Rotoiti trout, passage from one lake to another is impossible. Thus all the lakes may be termed land-locked as far as the trout are concerned. The various species of trout acclimatized in the lakes are as follows: The typical rainbow trout (*Salmo irideus*), which is not specifically distinct from the steel-head trout (*Salmo gairdneri*); the Kern River trout of California (*Salmo irideus gilberti*), characterized by having small scales and abundant spots which reach to the pectoral and ventral fins; the McCloud River trout of California (*Salmo irideus shasta*), which has a larger eye and smaller mouth than the typical form; the American brook charr (*Salvelinus fontinalis*); and the English brown trout (*Salmo fario*), which is not specifically distinct from the English sea-trout, *Salmo trutta*.

RADIUM EMANATION.

Farr and Florance (1910, pp. 185–90) and Farr and MacLeod (1911, pp. 55–57) have given the results of experiments of hatching trout in Christchurch artesian water highly charged with radium.

Maclaurin and Wright (1911, p. 63) have given a determination of the radio-activity in certain of the waters of the thermal district. They state: "Of the waters examined by us, those from the Hamurana and Fairy Springs are the most active. They are cold non-mineralized springs issuing from the base of the hills on the shores of Lake Rotorua. The Hamurana is a spring of very large dimensions, having a flow of about 5,000,000 gallons per diem."

During the spawning season the trout in Lake Rotorua seem to prefer to run from the lake into one of these cold spring creeks, many of which contain little natural food. In the spring of 1919 it was found that while the trout were packed together in a tributary of the Hamurana

apparently too closely to spawn, but few were to be found in tributaries of the Utahina, a watershed river some three miles distant.

The Fairy Springs commonly visited by all Rotorua tourists owe one of their chief attractions to the fact that practically the whole year numbers of trout may be seen circling in the waters. It is generally conjectured that, on account of their being fed by the owner of the springs, certain trout remain when others return to the lake at the close of the spawning season. This may in part be true; but as the same may be seen in a greater or less degree in the headwaters of all cold springs on the western side of Lake Rotorua, it is possible that the peculiar attraction of the trout to these waters may be determined largely by the high amount of oxgyen dissolved.

Farr and MacLeod (*loc. cit.*) confess their inability to decide between a defect of oxgyen and an excess of radio-activity as causing mortality in trout-young. As in the Hamurana and others we have the example of waters with a comparatively high radium emanation together with a high oxgyen content, it would seem that radium emanation in the amounts found has little effect on adult trout. The unfavourable results of Christchurch artesian water on young trout-life obtained by Farr and his co-workers may therefore have been due not to excess of radium emanation but to defect of oxygen dissolved, as they themselves point out.

SUGGESTED CLASSIFICATION.

All samples analysed contain silica, alumina, calcium, magnesium, chlorides, and carbonates, which for convenience have been combined as shown in the table of analyses. All would be classed as carbonate waters. The analyses suggest a division of the waters based on the following lines :—

(1.) The amount and nature of the mineral constituents. There is no line of demarcation between what may be called ordinary waters and mineral waters. According to Clarke (1908, p. 139) a mineral spring may be described as one which owes its character to local as distinguished from widespread or general conditions. In all water from the lakes in the thermal district the individuality of the characteristic features of the waters from cold springs, rivers, streams, or geysers is modified to a greater or less degree. Most of the samples, however, contain a similar amount of total solids to waters ordinarily used for potable purposes in New Zealand, the exceptions being Whakarewarewa, where the amount is a little more than the average, and Rotomahana and Tarawera, which are considerably above the average.

(2.) Suitability for potable purposes as indicated by the amounts of free and albuminoid nitrogen, dissolved organic matter, and the character of the deposit. The indications under this head are of considerable importance in considering the correlation of the water-constituents to fish-life. Under separate heads the various waters are discussed as to their relative suitability for potable purposes.

METHODS OF CHEMICAL ANALYSIS.

With the exception of the process used for the estimation of dissolved oxygen the methods of chemical analysis call for no special comment. The first part of the table represents the ordinary analysis as carried out for a water to be used for potable purposes, and the latter an analysis of

the mineral solids dissolved in the water. In expressing the latter results the elements have been combined in the customary arbitrary manner for the purpose of facilitating comparisons of the waters.

ESTIMATION OF DISSOLVED OXYGEN.

The process used for the estimation of dissolved oxygen is that of Dr. Thresh, as described by Kenwood, which provides a rapid alternative to the lengthy gasometric process when oxygen alone is required. As the method is not widely known, and as a slight modification in the apparatus has been introduced by which greater accuracy is possible, it is described here in some detail.

The method depends on the fact that when dilute sulphuric acid and potassium iodide are added to water containing nitrite, iodine is liberated, and the amount varies with the length of time during which the mixture is exposed to air. If air is excluded the amount of iodine liberated thus depends on the amount of oxygen dissolved in the water used, allowance being made for the oxygen dissolved in the chemicals used, and for any oxygen which may be taken up by nitrous acid in the nitrite or present as nitrite in the water.

The solutions required are—

(1.) Solution of sodium nitrite and potassium iodide (Sodium nitrite, 0·5 gram; potassium iodide, 20 grams; distilled water, 100 c.c.).
(2.) Dilute sulphuric acid (1 in 4).
(3.) Sodium-thiosulphate solution, 7·75 grams to the litre. (One cubic centimetre corresponds to 0·25 milligram of oxygen.)
(4.) Starch solution.

The accuracy of the process was examined by shaking distilled water with air for a period of thirty minutes and estimating the amount of oxygen dissolved in the water. The result obtained showed a fairly good agreement with the figure given in Seidell's "Solubilities of Inorganic and Organic Substances":—

	Temperature.	Milligrams Oxygen per Litre.
Result obtained	15·00° C.	10·25
Seidell	14·78° C.	10·10

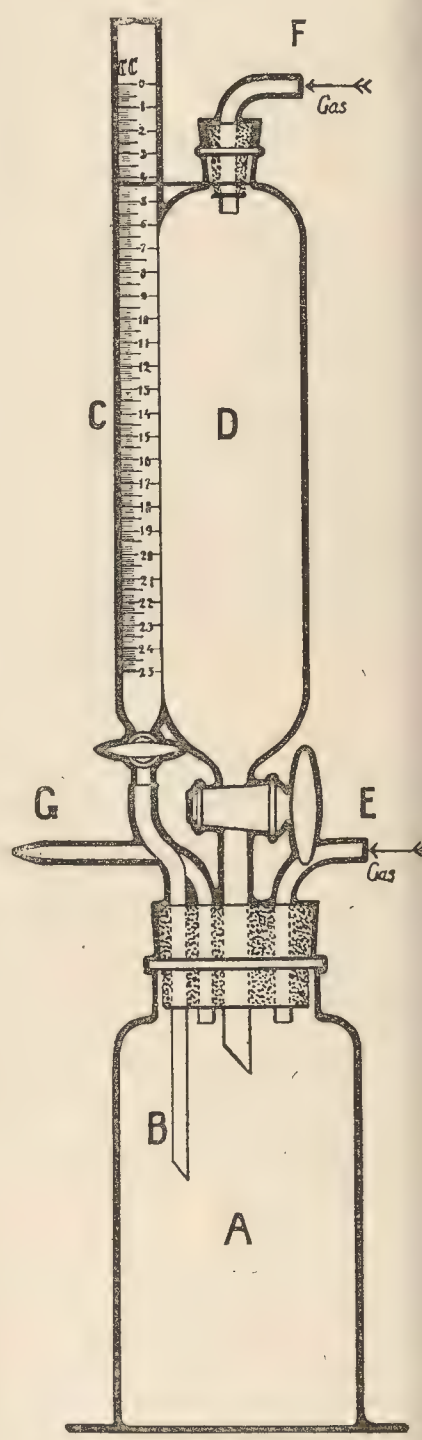
The apparatus used is shown in diagram.

With the apparatus described by Dr. Thresh the burette was not attached rigidly to the rest of the apparatus, but was connected by means of a piece of flexible rubber tubing to the bottle D. Considerable difficulty was found in obtaining a good end point to the titration, owing to the difficulty in discharging all the thiosulphate from the tube and in shaking the apparatus during titration. To obviate this the burette was attached as shown in the diagram, and with this apparatus duplicates were found to agree to within one drop of thiosulphate.

The method of procedure as described by Thresh is as follows:—

"The bottle A being clean and dry, the perforated bung is inserted, the burette charged, and the tube B fixed in its place. E is connected with the gas-supply. The tube D is filled to the level of the stopper with the water to be examined, then 1 c.c. of the solution of sodium nitrate and potassium iodide and 1 c.c. of the dilute acid are added, and the stopper instantly fixed in its place, displacing a little of the water and including no air. If the pipette be held in a vertical position, both the saline solution and the acid, being much denser than the water, flow in

a sharply defined column to the lower part of the tube, so that an infinitesimally small quantity (if any) is lost in the water which overflows when the stopper is inserted. The tube is next turned upside down for a few seconds for uniform admixture to take place, and then the nozzle is pushed through the bung of the bottle, and the whole allowed to remain at rest for fifteen minutes to enable the reaction to become complete. A rapid current of coal-gas is now passed through the bottle A until all the air is displaced and the gas lighted at G burns with a full luminous flame. The flame is then extinguished, the stopper of D removed, and the cork G rapidly inserted in its stead. On turning the stop-cock the water flows from D into the bottle A, which now contains no oxygen. The stop-cock is turned off, the cork G removed, and the supply of gas regulated so that a small flame only is produced when this gas is ignited at G. The thiosulphate is now run in slowly from the burette C until the colour of the iodine is nearly discharged. A little solution of starch is then poured into D, and about 1 c.c. allowed to flow into the bottle by turning the stop-cock. The titration with thiosulphate is then completed. After the discharge of the blue colour, the latter returns faintly in the course of a few seconds, due to the oxygen dissolved in the volumetric solution; therefore after about two minutes 0·1 c.c. of thiosulphate must be added to effect the final discharge. The total amount of thiosulphate solution used must now be noted. This will represent—(*a*) The oxygen dissolved in the sample used; (*b*) the oxygen taken up by the nitrous acid in the nitrite; (*c*) the oxygen dissolved in the reagents added; (*d*) any oxygen taken up by any nitrous acid present as nitrite in the sample.



"To find the value of (*a*), it is obvious that the value of (*b*), (*c*), and (*d*) must be ascertained. The value of (*b*) and (*c*) can be most readily found by making a blank experiment, by adding to the apparatus 2 c.c. of the nitrite-iodide solution, 2 c.c. of acid, 2 c.c. of starch, and distilled water equal to twice the volume of thiosulphate used in the analysis, and titrating with thiosulphate as in the actual experiment. Half the thiosulphate solution used represents the amount which must be deducted on account of (*b*) and (*c*).

"To find the value of (*d*), a water containing nitrates will require the amount of the nitrous acid to be determined if the utmost accuracy is required (a water containing 1 part HNO_2 in 1,000,000 will affect the results 0·17 milligrams of oxygen per litre; 94 parts of the acid corresponding to 16 of oxygen). Where nitrites are present in sufficient quantity to interfere, the amount may be determined by any of the ordinary processes."

WATERS ANALYSED.

To obtain the nature and amount of the deposits, the water in each case was allowed to stand for a period of twenty-four hours in the conical vessel usually employed for the purpose.

The temperature of various waters varied between 56° and 60° F.

Analyses of Thermal Waters, North Island, New Zealand.

Results expressed in Parts per 100,000.	Series I.							Series II.							Series III.	
	Hamurana Spring.	Waterfall Creek.	Waikuta Stream.	Whakarewarewa Stream.	Lake Rotorua.	Lake Rotoiti.	Lake Rotoma.	Lake Okareka.	Blue Lake.	Green Lake.	Lake Tarawera.	Lake Okataina.	Lake Rotomahana.	Lake Ngahewa.	Lake Taupo.	Lake Rotoaira.
Smell when heated to 100° F...	Faint.	Faint.	Faint.	Faint.	Faint.	Faint.	Faint.	Faint.	Faint.	Faint.	Faint.	Faint.	Faint.	Faint.	Faint.	Faint.
Chlorine in chlorides.. ..	1·24	1·24	1·06	10·29	3·73	2·84	4·08	0·89	0·89	1·24	14·20	2·13	62·83	1·06	1·60	1·06
Nitrogen in nitrates	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.
Nitrogen in nitrites	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.
Ammoniacal nitrogen from free and saline ammonia	0·0013	0·0012	0·0017	0·0100	0·0050	0·0028	0·0024	0·0016	0·0014	0·0015	0·0020	0·0022	0·0006	0·0035	0·0010	0·0016
Albuminoid nitrogen.. ...	0·0040	0·0021	0·0036	0·0049	0·0166	0·0108	0·0084	0·0019	0·0078	0·0102	0·0133	0·0042	0·0206	0·0108	0·0036	0·0042
Oxygen absorbed in four hours at 80° F.	0·001	0·001	0·008	0·076	0·089	0·036	0·007	0·034	0·018	0·026	0·022	0·015	0·029	0·164	0·007	0·013
Oxygen dissolved (milligrams per litre)	10·0	9·5	9·7	2·5	7·9	8·5	9·3	9·1	9·7	9·2	8·25	9·2	8·7	9·1	9·0	9·2
Sodium silicate ($Na_2O_4SiO_2$) ..	1·70	2·05	2·75	9·80	4·45	0 75	5·80	2·00	1·75	2·50	7·00	3·50	23·25	7·00	5·24	6·50
Alumina (Al_2O_3)	0·16	0·20	0·20	0·28	0·24	0·24	0·36	0·12	0·36	0·16	0·60	0·20	0·40	0·56	0·29	0·20
Calcium chloride ($CaCl_2$) ..	1·03	0·63	0·72	1·35	0·80	1·19	1·27	..	0·71	0·71	4·91	1·66	6·34	0·71	1·02	..
Magnesium chloride ($MgCl_2$) ..	0·38	..	0·05	0·57	0·47	0·78	0·47	1·19	0·66	0·76	4·65	0·47	3·44	0·28	0·46	1·33
Sodium chloride (NaCl) ..	0·50	1·37	1·02	14·66	3·37	2·57	4·81	..	..	0·33	10·84	1·18	93·61	0·64	0·47	0·12
Magnesium sulphate ($MgSO_4$)..	..	..	..	..	..	..	..	0·22	..	..	..	..	..	..	..	..
Sodium sulphate (Na_2SO_4) ..	..	..	..	7·72	3·33	4·00	..	3·25	2·72	1·15	11·36	..	11·43	..	..	0·67
Calcium bicarbonate ($CaH_2(CO_3)_2$) ..	..	..	..	..	..	..	..	3·24	..	..	..	..	..	..	..	4·89
Sodium bicarbonate ($NaHCO_3$)	4·70	3·36	2·35	..	2·86	1·93	2·10	2·18	0·84	2·27	18·98	4·45	17·38	1·18	3·50	..
Total solids	8·47	7·61	7·09	34·38	15·52	11·46	14·81	12·20	7·04	7·88	58·34	11·46	155·85	10·37	10·98	13·71

Hamurana Spring.

Sample collected directly from the largest Hamurana spring.

The deposit was very small, being mostly siliceous particles with a few diatoms. The free and albuminoid nitrogen and the oxygen absorbed are low, and the water may be regarded as excellent for potable purposes.

In the stream fed by this and like springs the growth of plant-forms such as *Nitella* and *Myriophyllum* is abundant. The *toi-toi* (*Gobiomorphus gobioides*) and the crayfish or *koura* (*Paranephrops planifrons*) are to be found in the stream in abundance during July, but when the trout run up-stream in the spring months their numbers perceptibly diminish.

WATERFALL CREEK.

Sample collected from a small creek close to Hamurana and emanating from a typical cold spring.

The water gave a small deposit consisting of numerous diatoms. This is an excellent potable water, being very similar to Hamurana. The total solid content is here very low.

Waikuta (or Hatchery) Stream.

Sample collected from spring supplying the hatchery water.

The water gave a small deposit consisting mainly of organic matter. Chlorophyceae and diatoms were abundant, and some fungi were also present.

The amount of albuminoid nitrogen is low, and the amount of oxygen absorbed satisfactory, indicating a fair potable water. The amount of oxygen dissolved is high and the total solid content low.

Whakarewarewa Stream.

Sample collected at a point below the geysers.

The deposit was large, consisting mainly of organic matter. Diatoms were abundant, and some fungi and protozoa were noted.

The total solid content is high, and the oxygen dissolved is very much lower than in other samples of water examined, being in this instance only one-fourth of the average. Chlorine in chlorides are here higher than usual. The sulphates present may have been derived from the oxidation of sulphurous acid or sulphuretted hydrogen. This water is of doubtful quality for potable purposes.

In the headwaters of this stream lives the American brook charr, (*Salvelinus fontinalis*), which does not migrate to the lake, and is found nowhere else in the district. Water the nature of the sample analysed would not long support animal-life, and the charr are thus prevented from passing to the lake.

Lake Rotorua.

Water from this lake was found to be high in organic matter, swarms of diatoms and abundant chlorophyceae and protozoa being present. The analysis indicates a water highly favourable to organic life.

The total solid content of Lake Rotorua is 15·52, that of Hamurana 8·47, and that of Whakarewarewa 34·38. From this it is evident that he sample of Rotorua water is somewhat intermediate in composition

between that of typical cold spring water and waters overflowing from geysers. In the amount of oxygen dissolved Hamurana sample has 10·0 parts, Whakarewarewa 2·5 parts, while in Lake Rotorua there is 7·9 parts per 10,000.

There can be no doubt that in the past the higher forms of life were much more numerous than at present, but with the introduction of trout, small fishes, crayfish, and insects have all declined in numbers, and it is evident that the lake is now stocked with large numbers of trout of a small size so numerous as to be out of proportion to the existing food-supply.

Lake Rotoiti.

The deposit was found to be of medium size, containing, as in the case of Rotorua water, swarms of diatoms and abundant chlorophyceae and protozoa. The water contains rather too much albuminoid nitrogen to be classed as a good drinking-water.

This lake, which receives the surplus water from Lake Rotorua, has a lower total solid content than its neighbour. The analysis shows also a higher quantity of oxygen dissolved and an increased quantity of sulphates.

Trout in this lake are rarely poor-conditioned. Dredging revealed a copious food-supply, and it appears that the nature of the bottom is peculiarly favourable to the growth and development of algae and diatoms on which crayfish feed. A small fish, *Galaxias brevipinnis*, is also more common in this lake than elsewhere.

Lake Rotoma.

The deposit was small. Large numbers of diatoms and some chlorophyceae were detected. The water would be regarded as of fair quality for potable purposes.

Lake Rotoma, which is situated due east of Lake Rotorua, supports only a small number of trout, the majority of which are in fair condition. As only one very small stream enters the lake, but few trout are able to spawn annually. Constant restocking with trout-fry is therefore necessary.

Lake Okareka.

The deposit was small, consisting chiefly of siliceous particles with some organic matter. Several diatoms were present. The water is of good quality for potable purposes. The total solid content of Lake Okareka more nearly approximates that of Lake Rotoaira spring water than any other sample of water analysed.

The trout in this lake are in excellent condition and of a very large size. *Koura* and *toi-toi* are abundant.

Tikitapu, or Blue Lake.

The deposit was of medium size, consisting of coarse siliceous particles and some organic matter; a few protozoa and one or two diatoms were noted.

This lake has the lowest total solid content of those examined. The ratio of albuminoid nitrogen to oxygen absorbed is higher than in the mineral waters of Rotorua and also of Lake Taupo. The water may be considered satisfactory for potable purposes.

Food-supply is not abundant, and trout are for the greater part of small size.

Rotokakahi, or Green Lake.

The water gave a small deposit consisting of organic matter and siliceous particles. A number of diatoms and one or two chlorophyceae were present.

Sodium sulphate is less than in Tikitapu, the waters of which Rotokakahi receives. The total solid content is noticeably low. The albuminoid nitrogen is rather high, and the water is only of fair quality for potable purposes.

Although food seems abundant in certain parts of the lake, the trout are generally in poor condition.

Lake Tarawera.

The water gave a moderately large deposit consisting of organic matter and coarse siliceous particles. Numerous protozoa and some diatoms were present.

The albuminoid nitrogen is high, and its ratio to the amount of oxygen absorbed is also high, indicating that the water could not be classed as good for potable purposes. The total solid content is much higher than usual.

This lake, which has not yet recovered from the eruption of Mount Tarawera in 1886, supports only small communities of *toi-toi*, molluscs, and crayfish. Plants are numerous around the mouths of streams flowing into the lake. The trout are for the greater part in poor condition, and seem unable to gain an adequate food-supply.

Lake Okataina.

The water gave a small deposit, mainly of organic matter with some siliceous particles. Numerous diatoms were present and a few cyanophyceae. Water of good quality for potable purposes.

The trout in this large isolated lake are all of a large size and healthy. Insect food from the surrounding bush appears to be common, as are the *toi-toi* and *koura* in the lake itself.

Lake Rotomahana.

The deposit given was rather small, consisting of organic matter with some coarse siliceous particles. A number of diatoms and one or two protozoa were present. The albuminoid nitrogen is high, and the large total solid content, which is much higher than in other samples, indicates that the water is not suitable for potable purposes. Certain parts of the lake are boiling continuously. The chlorine content is approximately twenty-one times greater than that of Rotorua.

The trout are mostly large adults, but are not numerous. Recently anglers have taken a few very large and healthy examples. Trout-fry do not readily flourish in this water, due probably to the high total solid content.

Lake Ngahewa.

The deposit was small, containing some organic matter. Numerous diatoms and chlorophyceae were present. The oxygen absorbed and the albuminoid nitrogen are somewhat high, indicating the water is only of fair quality for potable purposes.

Lake Ngahewa lies at the foot of Kakaramea (or Rainbow) Mountain, and to the south-west of Rotomahana. It contains only a few small trout.

Lake Taupo.

The deposit was very small, consisting mainly of siliceous particles. Some diatoms and a few chlorophyceae were present. The water from this lake is quite satisfactory for potable purposes, and contains a relatively small amount of total solids.

In most of the shallow parts of the lake trout-food was in abundance, small fishes, crayfish, and plant communities being particularly common over large areas on the floor of the lake off the western shore. The trout are generally found to be in good condition, and have improved greatly during the past four years.

Lake Rotoaira.

Sample analysed was taken from water entering the lake from a subterranean channel.

The deposit was small, consisting of numerous chlorophyceae and some diatoms. Though containing a fairly high percentage of sodium silicate, the water is of good quality for potable purposes.

Lake Rotoaira, which is the most southerly of the lakes, lies at the base of Mount Tongariro. It contains very few trout.

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THE KAURI FOREST.*

By T. F. CHEESEMAN, F.N.Z.Inst., F.L.S., F.Z.S.

THE kauri pine (*Agathis australis*), the most noble and impressive of the forest-trees of New Zealand, and one with few equals in other countries, has a limited range, being confined to the district between the North Cape and a line drawn from Tauranga Harbour on the east coast to Kawhia on the west. Although it will flourish in almost all soils and situations save those which are exceedingly wet, it prefers hilly and somewhat rugged localities, and a poor and clayey soil. Usually it forms little clumps or small groves rather than continuous forests. These groves may contain from a dozen to a hundred or many hundreds of trees. Usually they are separated by forest tracts in which few kauris are present. Rarely the groves may almost coalesce, forming a forest in which the kauri is the dominant although by no means the sole tree. Nowadays such instances are rare ; for the ravages of sixty years of sawmilling have swept the forest out of existence, or very greatly changed its appearance, reducing what was once a noble and magnificent spectacle to a scene of utter ruin and desolation.

A kauri forest has a very remarkable and distinctive appearance. Even when seen from afar it can be recognized by the manner in which the trees stand far above the adjoining forest, by their peculiar ramification, and by the dark, dusky-green colour of the foliage. But it is from the interior of the forest that the kauri is seen to the best advantage, and its majestic size and noble proportions can be best appreciated. On all sides rise the huge columnar trunks, sometimes towering up for more than 80 ft. without a branch, and tapering but slightly from the base upwards, smooth, grey, and glistening. At the base of the trunk is the large mound of debris produced by the fall of the bark, which is regularly cast off in large flakes. It is from this peculiarity that the bole of the kauri is so free from the climbers and epiphytes that commonly clothe the larger trees of the New Zealand forest. From the top of the trunk spring, almost from one point, the short but immensely thick branches. These, with the branchlets and foliage, form a high vaulted roof to the forest, through which a varying amount of daylight filters to the ground. As large trees of other species seldom grow plentifully intermixed with the kauri, the forest has an open appearance not usually seen in the New Zealand woodlands. Under the vaulted roof of branches the eye can penetrate far and wide among the massive trunks, which have hence been compared to the pillars of some vast Gothic cathedral.

So much for the physiognomy of the kauri itself. But one of the most distinctive features of the kauri grove of any size is the peculiar nature of the associated vegetation. Although few really large trees grow intermixed with the kauri, smaller trees and shrubs do, together with certain herbaceous plants and ferns. And wherever a clump of kauri exists these

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* This note, which is condensed from the author's description of plate 184 in the *Illustrations of the New Zealand Flora*, vol. 2, 1914, is reprinted from the *Handbook for Scientific Visitors*, Wellington, 1914, a booklet prepared in anticipation of a visit of members of the British Association. The number of copies of this publication printed and distributed was very small.

plants are found, or, at any rate, the greater portion of them. Space does not permit of a full account, but it may be allowable to mention the names of prominent species. Of shrubs or trees there are the taraire (*Beilschmiedia tarairi*), the neinei (*Dracophyllum latifolium*), the mairehau (*Phebalium nudum*), the tapairu (*Senecio Kirkii*), and the climbing ratas (*Metrosideros florida* and *M. albiflora*). Of non-shrubby plants the most noteworthy are the "kauri-grass" (*Astelia trinervia*) and *Gahnia xanthocarpa*, together with the ferns *Lomaria discolor* and *Lygodium articulatum*. These, and many others, are those which delight to grow in association with the kauri, although by no means so certain to appear in company in the ordinary forest.

A young kauri—say, from fifty to a hundred years old—differs entirely in appearance from the mature tree. It has a narrow conical and sharply pointed outline, and is furnished with a succession of short slender branches inserted at right angles to the stem. As the tree increases in size the lower branches are cast off one by one, but it is only by slow degrees that the bushy-topped shape of the adult is assumed. It is a curious fact that young kauris are not commonly found among the mature trees, the reason probably being that the amount of light is not sufficient for the growth of the very young tree. The juvenile kauri is usually found on the outskirts of the forest proper, and is accompanied by such trees as the white tea-tree (*Leptospermum ericoides*), the towai (*Weinmannia sylvicola*), the toru (*Persoonia toru*), the maire (*Fusanus Cunninghamii*), the rewarewa (*Knightia excelsa*), and others. Such localities have been very truly called the nursery of the kauri. Granted sufficient time, this mixture of young kauris and other trees would develop into a forest of mature kauris; and in point of fact the intermediate stages can be observed without difficulty.

One of the most interesting of the peculiarities of the kauri is its copious production of a resin to which the name of "kauri-gum" is ordinarily applied. In a fresh state every part of the kauri is filled with a transparent turpentine, which exudes from the slightest wound. An injury to the bark, a broken branch, even bruised leaves, at once cause a copious flow. At first soft and viscid and of whitish colour, it gradually hardens on exposure to the air and becomes more transparent, forming lumps ranging in size from small tear-drops to masses many pounds in weight. These pieces may be found in the forks of the branches, in hollows or depressions on the trunk, or concealed in the mound of debris at its base. But, in addition to the resin met with in the living kauri forest, very much larger quantities can be found buried at various depths on the sites of previous forests, although these must have ceased to exist for hundreds or even many thousands of years. That these deposits are in many cases of enormous antiquity can be proved by the changes that have taken place in the physical configuration of the country since they were formed. Kauri-gum has been found under the beds of shallow lakes; it has been dug up in quantity at considerable depths in swamps; and it has been excavated from strata overlaid by sand-dunes themselves of no very recent formation; while in not a few localities it has been observed in beds dipping under the present level of the sea, and on the Auckland Isthmus in strata overlaid by lava-streams.

All through the North Auckland Peninsula are large areas of rolling open lands of poor quality, intersected by swampy gullies, and covered with a heath-like vegetation mainly composed of tea-tree (*Leptospermum*

scoparium) and other shrubs, together with sedges, a few herbaceous plants, terrestrial orchids, and some ferns. Almost everywhere these areas contain deposits of kauri-gum—sometimes close to the surface, at other times buried at considerable depths. These "gumfields," as they are called, have for many years afforded a living to some thousands of "gum-diggers," who annually produce from 7,000 to 10,000 tons of gum. These nomadic diggers, wandering over hill and swamp, armed with spade and gum-spear, are a familiar and picturesque sight to travellers in the North Auckland districts.

It may well be asked in what manner did the kauri forests of the past disappear, what vegetation succeeded them, and what have been the series of changes which have resulted in the present plant-covering of the gum-fields. The answer to these questions is, however, still uncertain and incomplete.

MAORI "GOD-STICKS" (WHAKAPAKOKO RAKAU).

By H. D. SKINNER, Lecturer on Ethnology, Otago University, Dunedin.

THE collections of the University Museum of Archaeology and of Ethnology, Cambridge, are particularly rich in material from New Guinea and the South Seas. The Fijian section, brought together by Baron Anatole von Hügel, who was for nearly forty years curator of the museum, is acknowledged as the finest in the world. The Maori collection is extensive, and contains some of the finest pieces in existence, especially notable being the feather-boxes, the flutes, the material brought home by Captain Cook, and the splendid wooden bowl in the form of an animal, with decorative carving in the highest class of Maori workmanship. There is also a large Moriori collection.

When in Cambridge in the years 1917–18 I drew up a card calalogue of the Maori and Moriori articles in the museum. The following notes were then made regarding the *whakapakoko rakau*, or "god-sticks," shown in fig. 1, A and B, for photographs of which I have to thank Dr. A. C. Haddon, F.R.S., and Mr. W. Bird :—

"No. 1.—Height, 36 m. The face is represented in the conventional Maori manner. One shell eye-circlet, with serrated edge, is in place; the other is lost. The flax cord is wound round the shaft straight, probably replaced thus by some former European owner. The head and the flax are painted red. History unknown, but on the back is pencilled 'Maru,' and 'F.M. No. 1. 9/12/84.'"

"No. 2.—Height, 37·5 cm. Face of unusual type, but mouth of conventional shape. Flax cord wound round shaft in complex criss-cross. Head and flax painted red, bottom of shaft black. Eye-circlets missing. On the back is pencilled 'Kahukura.'"

"No. 3.—Height, 37 cm. Face of very unusual type. Eyes countersunk to hold shell, but without the usual central peg. Hands shown, with five fingers on each. Upper part painted red, lower black. On the back is written, in ink, 'Hukere. Wanganui. G... [indecipherable]. New Zealand.' And in pencil, 'Hukere' 'F.M. 9/12/84. No. 3.'"

On comparing the photos kindly sent me by the authorities at Cambridge with the illustrations of Richard Taylor's work, *Te Ika a Maui* (London, 1855), it was apparent that the Cambridge *whakapakoko rakau* were the very ones which Taylor drew to illustrate his book, though Taylor showed an additional one of unusual type. Taylor was stationed in the Wanganui district, a fact which supports the accuracy of the details pencilled on the figures. His drawing is remarkably accurate, differing from fig. 1 only in the fact that the cord is not coiled straight round the shaft of No. 1, but is latticed like that of No. 2, and encloses round its upper margin a circlet of feathers.

Taylor's remarks about these figures are of great interest. He says (p. 72): "In the south [of the North Island] a small kind of image was used, about 18 inches long, resembling a peg, with a carved head, *he waka pakoko rakau*. The priest first bandaged a fillet of red parrot-feathers under the god's chin, which was called his *pahau* (beard); this bandage was made of a certain kind of sennit, which was tied on in a peculiar way. When this was done it was taken possession of by the *atua*, whose spirit entered it. The priest then either held it in the hand and vibrated it in the air, whilst the powerful *karakia* was repeated, or he tied a piece of string (formed of the centre of a flax-leaf) round the neck of the image, and stuck it in the ground. He sat at a little distance from it, leaning against a *tuahu*, a short stone pillar stuck in the ground in a slanting position, and, holding the string in his hand, he gave the god a jerk to arrest his attention. He then repeats his *karakia* in a quick singing tone. This being finished, he took a short piece of fern-stalk, which he stuck into the ground; he then gave the god another pull, uttered another *karakia*, and stuck another piece of fern-stalk into the ground; and thus he continued until he had repeated all his *karakia*, which he counts by fern-stalks. The god is supposed to make use of the priest's tongue in giving a reply. Image-worship appears to have been confined to one part of the Island. The *atua* was supposed only to enter the image for the occasion. The natives declare that they did not worship the image itself, but only the *atua* whom it represented." Later, in describing the rite of baptism, Taylor states that the *waka pakoko rakau* was placed against the child's ear that the *mana* (virtue of the god) might be transferred to the child.

As local god of war, Maru occupied a more prominent place in the Wanganui-Taranaki district than elsewhere in the New Zealand-Chatham area, though he was everywhere known. He is presumably a deified ancestor, as it is recorded of him (Taylor, p. 81) that he was killed and eaten when on earth. I do not know whether Kahukura was more prominent in the Wanganui-Taranaki district than elsewhere; he also was known throughout the New Zealand-Chatham Islands area.

I am not aware that the name or functions of Hukere have been recorded, apart from the note on No. 3. The rendering of the head differs fundamentally from that of Maru (No. 1), which exemplifies the usual Maori rendering in the round. The rendering of the teeth—three lateral on either side and two median—is perhaps to be compared with the dentition of the figure on the skull-box in the Auckland Museum, figured in *Man* (1918, June, plate F, No. 4). This box has a sharpened peg, so that it might be fixed in the ground erect. The two renderings of the face have other points in common, but there are also important differences.

FIG. 1 (A).

FIG. 1 (B).

Sets of *whakapakoko rakau* are by no means common. They appear usually to go in threes. Thus a trio were secured by the Rev. J. Aldred, in the "forties," at a village between the present towns of Pâtea and Hawera. This set, which was recently bequeathed to the Auckland Museum, has been figured several times.* Hamilton calls the figures *atua whawhia*, or *tiki*, and says that Mr. J. North believes them to represent Maru, Rongo, and Tangaroa. In *Hawaiki* it is stated that the figures actually represent these deities. but the authority is not given. One member of the set is a Janus with two faces, while another approximates in some respects to Hukere of the Cambridge set. A third set of three, also from Wanganui, is in private hands, and is figured by Hamilton.† One member of this set is Janus. A fourth set of three is in the British Museum collection, and is figured by Hamilton.‡ This set resembles that at Cambridge, but is not so fine.

FIG. 2.

Single examples of *whakapakoko rakau* also occur. Two are figured by Hamilton,§ who does not record the locality, and I am able to figure one here (fig. 2). When in England I attempted to make a census of all Maori material in museums, and while engaged on the Maori collection in the admirable Bankfield Museum at Halifax I met the honorary curator, Mr. H. Ling Roth, well known for his researches in more than one department of ethnology. After my return I received from him an illustrated catalogue of the collection. The catalogue, which had been drawn up and bound at the expense of the Halifax Education Committee, was presented by them to the library of the University of Otago "for the use of New Zealand students," and I am glad of this chance of thanking them and publishing their gift. The illustrations are in part photographs, in part drawings by Mr. Comfort (famous for his work in the *Graphic* when that paper was illustrated by wood-blocks), and partly pen-drawings by Mr. Ling Roth himself. To these last belongs fig. 2, an excellent example, of which, unfortunately, the provenance is unknown. Two other examples were in the hands of Mr. Oldham, the well-known dealer. Finally, there is an interesting and exceptionally fine Janus from Otago in the collection of Mr. Willi Fels, Dunedin.

The distribution of this type of figure is interesting. Taylor states that they were confined to "the south," by which he seems to mean the Wanganui-Taranaki district; Mr. Fels's example indicates their existence in Otago; while Shand's researches show them to have been present at the Chathams. Allied forms are present in Melanesia (New Hebrides) and Polynesia (the hypertrophied "idols" of the Cook and Society Groups, but particularly the *moa atua* of Nukuhiva). The poverty of our libraries and museums prevents the New Zealand student from tracing them further, though it is probable that related forms exist in Indonesia.

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* HAMILTON, *Maori Art*, plate 59, fig. 2. PERCY SMITH, *Archiv. für Eth.*, Bd. xii, p. 223. PERCY SMITH, *Hawaiki*, 4th ed., p. 240.

† *Dom. Mus. Bull. No. 3*, p. 105.

‡ *Maori Art*, plate 57, fig. 2.

§ *Dom. Mus. Bull. No. 3*, p. 105.

DEPARTMENTAL REPORTS.

The Genesis of the Puhipuhi Cinnabar Deposits: A Working Hypothesis.

By W. H. CROPP, A.O.S.M., N.Z. Geological Survey.

INTRODUCTION.

THOSE interested in the Puhipuhi cinnabar deposits have been accustomed to regard them as the outcrop portions of deep-seated lodes, but recent work by the Geological Survey suggests an altogether different explanation. This the writer herein endeavours to present in condensed form, together with an outline of the later events in the geological history of the Puhipuhi district. An attempt is also made to explain these events in terms that will afford assistance in the economic development of the known deposits and be a guide in the search for new ones. It is imperative, in the search for and extraction of commercial minerals, that all outlay of energy and capital shall be ensured the greatest chance of success. That the area merits research will be at once conceded when it is known that already some 16 tons of metallic quicksilver have been marketed, and that several hundred thousand tons of workable ore are probably present.

The writer is under a deep obligation to the Geological Survey for the opportunity to study the area, and to its Director for his courtesy in permitting the presentation of this summary of the work and its results.

GENERAL OUTLINE OF GEOLOGY.

The area including all the known cinnabar occurrences consists of an oldermass of much-jointed greywacke belonging to the Waipapa formation.* On this lie flows of basalt of the Kerikeri series so disposed as to form the caps of two plateaux, one at 1,300 ft., the other at 800 ft., above sea-level. The greywacke is crossed by zones of weakness which are belts of shattering rather than of displacement. The principal visible evidence of their presence is the abundance of surface deposits of various forms of siliceous sinter, which have been left by numerous geysers and hot springs rising along them. A notable line of these quartz "blows" stretches northwards for three miles from "Mount" Mitchell, a hillock rising some 50 ft. above the general level of the lower plateau. This line will be referred to as the "Waikiore fault." Many quartz masses occur in the eastern portion of the district, but apparently without defined arrangement.

Along the Waikiore and associated fractures there was intense hydrothermal activity, which in its expiring phase was accompanied by mineral-bearing solutions.† The period of this activity was presumably late

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*See H. T. FERRAR, *N.Z. Jour. Sci. & Tech.*, vol. 4, p. 312, 1922. A table summarizing the geological formations in North Auckland is there given.

†McKAY (parl. paper C.–9, 1898, p. 8) and FRASER (The Geology of the Thames Subdivision, *N.Z. Geol. Surv. Bull. No. 10*, n.s., 1910, pp. 65–66) describe cinnabar in siliceous sinter near Thames. BELL and FRASER, in the Geology of the Waihi-Tairua Subdivision, *N.Z. Geol. Surv. Bull. No. 15*, n.s., 1912, pp. 119–21, give a description of the cinnabar-bearing sinter beds of Mackaytown, near Karangahake.

Pliocene, the evidence of this being (*a*) superficial silicification of the upper layers of Pliocene leaf-beds in the valley of the Waikiore Creek; (*b*) absence of silicification in the Kerikeri (Pliocene to Recent) basalts, although flows of these rocks overlie several of the quartz masses. Thus the silicification (and mineralization) occurred in the Pliocene just prior to the extrusion of the Kerikeri basalts. The invasion of the district by these basalt-flows was the last of the main geological events so far as the mineral deposits are concerned.

THE HYDROTHERMAL PHASE IN DETAIL.

The ascending siliceous thermal waters, arriving at the surface, cooled and laid down mounds of sinter round the vents. In many cases deposition continued quietly, and, before it ceased, sheets of chalcedonic silica of considerable size had been laid down on the greywacke land-surface. The greater part of both the Mount Mitchell and Pataua Falls sheets are examples.

At the head of the Waikiore Creek, however, increased activity in several of the vents developed an explosive phase. New vents were formed and the silica deposits in their vicinity shattered. More distant portions of the deposits were less disturbed, and now show as banded chalcedony with the bands unaltered or only slightly contorted. The turbulent waters of the new vents ejected all the smaller products of shattering, and these, settling near-by, were cemented by fresh sinter into a compact mass—a typical recemented breccia. The continuous abrasion of the larger masses remaining in the throats of the vents rendered the overflow milky with fine silica particles. This silica settled in pockets, forming the siliceous "pug" common in the workings of the New Zealand quicksilver-mines and also under parts of the Mount Mitchell sinter sheet. Somewhat similar events took place in the Rising Sun area, and doubtless also in other parts of the upper plateau now covered by basalt.

Thermal activity at the head of the Waikiore Creek and in the Rising Sun area now waned, and silica apparently disappeared from the still hot waters, giving place to mercury sulphide in solution. Incoherent, finely crystalline cinnabar filled interstices and vugs, and covered quartz surfaces of the shattered upper portion of the sinter sheets. Probably these waters were similar in composition to those now depositing cinnabar near Ohaeawai, some twenty-two miles to the west.*

At Mount Mitchell the mercury appeared as an additional constituent in the siliceous waters, from which silica and cinnabar were deposited simultaneously. The result is a beautiful vermilion-stained chalcedony, in which, however, the red colour of the freshly broken surfaces quickly changes to bluish-grey by exposure to daylight.

Rapid decline in the thermal activity was marked by the disappearance of cinnabar from the waters over the whole area. At Mount Mitchell deposition ceased entirely. At the Waikiore and Rising Sun deposits the almost cold waters now deposited iron sulphide, which forms a surface

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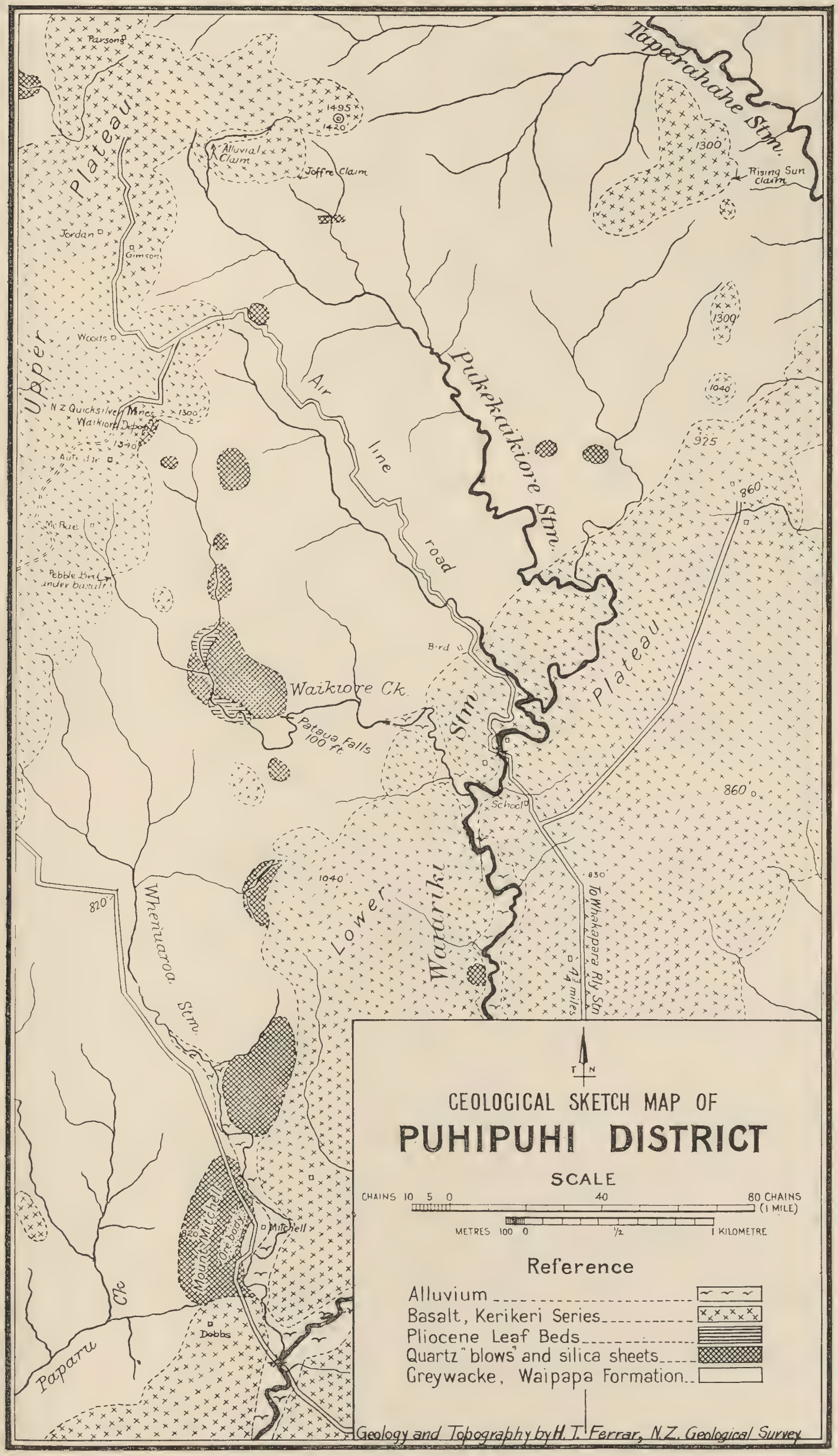
* See J. M. BELL and E. de C. CLARKE, Geology of the Whangaroa Subdivision, *N.Z. Geol. Surv. Bull. No. 8*, n.s., 1908, pp. 38, 87. For the reactions entailed in the deposition of cinnabar by thermal waters the reader is referred to the various text-books on economic geology, most of which give summaries of Becker and Melville's work on this question.


GEOLOGICAL SKETCH MAP OF
PUHIPUHI DISTRICT
SCALE
CHAINS 10 5 0 40 80 CHAINS (1 MILE)
METRES 100 0 ½ 1 KILOMETRE
Reference
Alluvium
Basalt, Kerikeri Series
Pliocene Leaf Beds
Quartz "blows" and silica sheets
Greywacke, Waipapa Formation
Geology and Topography by H. T. Ferrar, N.Z. Geological Survey
Upper Plateau
Tapatahahe Stm.
Pukekaikiore Stm.
Waikiore Ck.
Lower Waiariki Stm.
Whenuaroa Stm.
Paparu Ck.
Air line road
Parsons
Alluvial Claim
Joffre Claim
Rising Sun Claim
Jordan
Gimson
Woods
N Z Quicksilver Mines
Waikiore Deposit
McRae
Pebble Bed under basalt
Bird
Pataua Falls 100 ft.
School
To Whakapara Rly Stn
4¾ miles
Mount Mitchell
Ore body
Mitchell
Dobbs
1495
1420
1300
1340
1040
925
860
830
820

layer of marcasite varying from a few inches to several feet in thickness.* This marked the final phase of thermal activity in the district. The cinnabar and marcasite phases of deposition seem to have been local and distinct. Minute amounts of cinnabar may be found in the marcasite layer, and *vice versa*, but these are probably migrations.

The masses of siliceous sinter, especially the shattered deposits characteristic of the upper plateau, were now more or less denuded, and cinnabar-bearing gravels were formed. The marcasite was oxidized so that in places these deposits are now represented by friable limonitic sinter containing lenses and irregular lumps of sulphide. Later the extensive basalt-flows that cap the plateau spread over the land-surface and covered the sinter deposits and gravel-beds.

Subsequent stream erosion along the edge of the upper plateau has exposed several deposits of cinnabar-bearing sinter and gravels. The cinnabar fragments in the beds of the existing streams have been derived from these deposits.

ECONOMIC SIGNIFICANCE OF THESE EVENTS.

On the assumption that the foregoing is a correct interpretation of the evidence exposed, some general guiding principles may be deduced for use in present and future development of the cinnabar resources of the district. The conception of "reefs," which immediately occurs to the metal-miner, and which influenced the earlier mining operations at Puhi-puhi, now passes. The Mount Mitchell quartz masses are not the sheddings of a hidden reef—the view which lay behind the several drifts beneath it—but form a surface sheet probably not exceeding 30 ft. in thickness. The extraction of its cinnabar-bearing portions calls for quarrying, not mining, operations.

The sinter sheets containing the ore-bodies at Waikiore and the Rising Sun almost certainly resemble in their general shape and dimensions those occurring at Mount Mitchell and Pataua Falls. Exploration should therefore be lateral rather than in depth, and it is the marcasite layer that should be followed by the underground workings. Not only does it mark the surface contours of the buried sheets and the upper limit of the cinnabar-bearing layer, but the cinnabar seems to be most concentrated immediately below it. Locally it is called the "hanging-wall" of the ore-body, although, in view of the genesis of the deposits, "roof" would be a more suitable term.

Up to the present prospectors have concentrated attention on the alluvial cinnabar in the present streams draining off the upper plateau. In view, however, of the source of this cinnabar, attention should be directed to the ancient stream-gravels underlying the basalt. Lying between the basalt and the greywacke near the head of the Pukekaikiore Stream, a 6 ft. bed of these old gravels was worked in the Joffre Claim. Some 20 chains distant a swampy stream, draining across an inlier of greywacke in the basalt, shows numerous rewashed cinnabar pellets in its muds. Somewhere along its course this swampy stream probably cuts across the continuation of the Joffre gravels, whence it derives its cinnabar. It should not be difficult to find this crossing-point, and so fix two

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* For the conditions of deposition of marcasite see E. T. ALLEN, Sulphides of Iron and their Genesis, *Mining and Scientific Press*, vol. 103, p. 413, 1911; also *U.S. Geol. Surv. Bull. 625*, p. 455, 1917.

positions on the general direction of the ancient stream, the buried gravels of which carry pellets of nearly pure cinnabar in notable quantity.

Prospecting efforts should be concentrated on the greywacke detritus close under the lower edge of the basalt of the upper plateau. It is along this contact that new finds of cinnabar *in situ* or in old gravels are most likely to be made, because of these deposits having been buried by the basalt and protected from erosion. Every stream at present draining from the upper plateau may cut across new ore-bodies or these old gravels. The many streams that show cinnabar pellets in their beds clearly do so. The first prospecting should be done where the headwaters of these streams cross the basalt-greywacke contact. Careful panning of the greywacke detritus below the basalt at these points will probably reveal cinnabar in the clay. The next step is simple trenching up the slopes to the basalt until the gravels or other source of the cinnabar is revealed.

It must be emphasized here that all such discoveries should have their localities exactly described, so that they may be plotted on a map and have their geological significance considered. If occasion arise, any mining-works aiming to follow these gravels or to explore beneath the basalt may thus be given positive guidance.

Similar prospecting in the vicinity of the known ore-bodies at Waikiore and the Rising Sun may well discover extensions beyond the present known limits. The discovery of the ore-body in the latter area demonstrates how thin a layer of clay can obscure deposits such as these.

All the quartz "blows" in the Puhipuhi district are worth systematic examination by chipping their surfaces. It was not until the accidental breaking of an apparently worthless quartz boulder revealed the scarlet interior that the Mount Mitchell cinnabar deposit was discovered.

Notes to accompany a Geological Sketch-map of the Marakopa District.

By J. HENDERSON and L. I. GRANGE, N.Z. Geological Survey.

INTRODUCTION.

THE writers, while examining the Kawhia district, had the opportunity of making two brief trips into the geologically unknown Marakopa district, which adjoins on the south. The senior writer travelled from Kinohaku, a township on a southern arm of Kawhia Harbour, to Te Anga, on the Marakopa River, a distance by road of eleven miles, and from there to Marakopa, the township at the mouth of the river. Thence he went by way of the Kiritehere Valley and Pomarangei Road to Waitanguru, a township seventeen miles nearly due west of Te Kuiti. Had it not rained nearly the whole time (from the 7th to the 13th April inclusive) the observations would have been less meagre. The junior writer, on the 25th March, 1921, travelled five miles south along the coast from the native village of Mitiwai in order to examine a deposit of iron-ore near Harihari. He was then surveying the adjoining Albatross Survey District, and had time only for this one excursion.

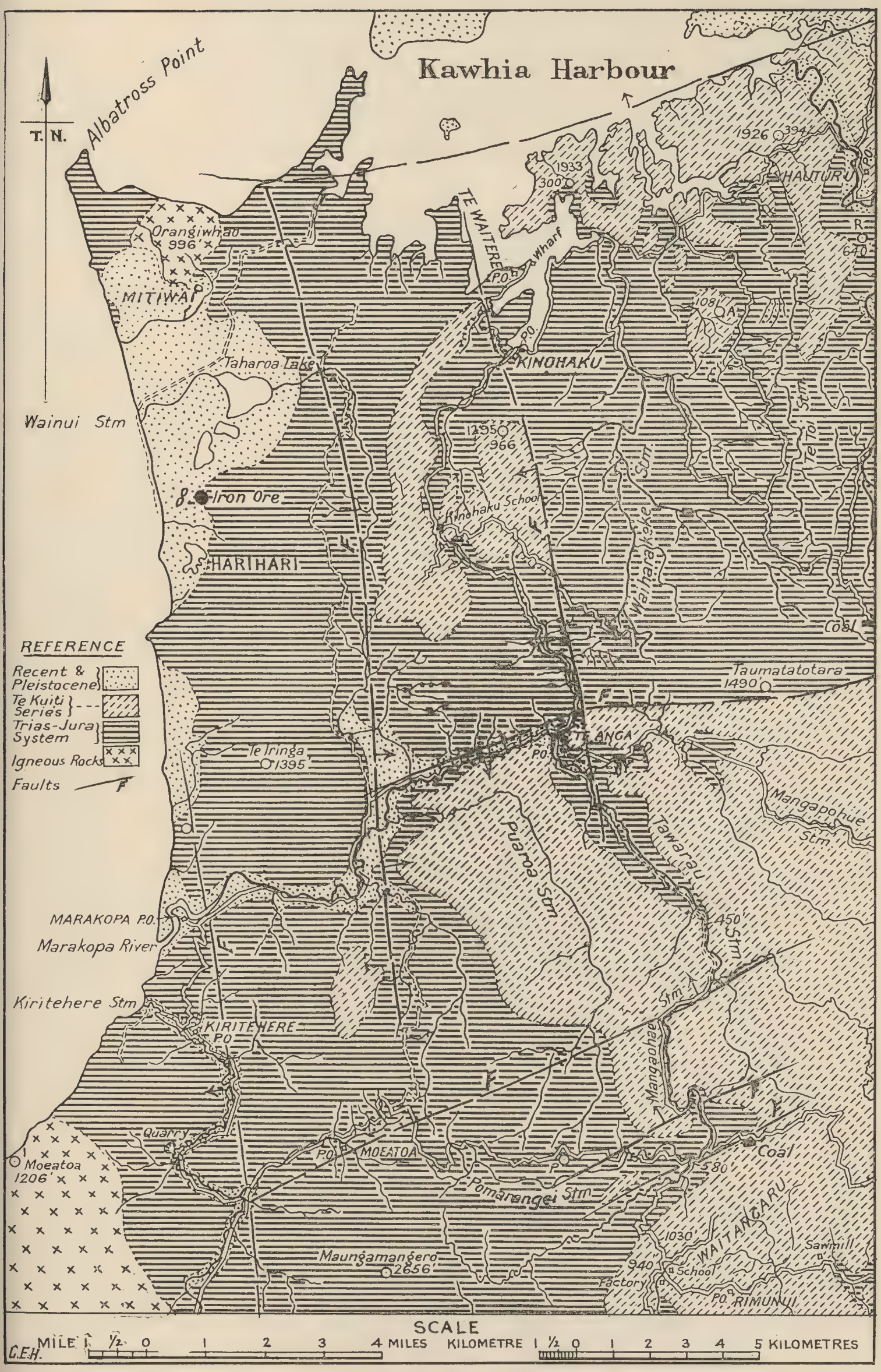
The Marakopa district, which has been only in part cleared of the bush that once covered it, is as yet entirely dependent on the grazing industry. Sheep and cattle are fattened, and dairy factories have been

established at Waitanguru and in the Marakopa Valley, about three miles west of Te Anga. The principal settlements are at Kinohaku, Marakopa, and Waitanguru. Small coastal vessels trading from Waitara used to cross the dangerous Marakopa bar into the river-estuary, but now most of the trade is through Kinohaku, which is served by launches from Kawhia. Coastal steamers from Onehunga call at the wharf at Te Waitere, near Lemon Point, two miles north of Kinohaku. The Waitanguru district is supplied from Te Kuiti.

PHYSIOGRAPHY AND STRUCTURE.

The Marakopa district is part of a broken and deeply dissected plateau that backs the coast from the mouth of the Waikato River to Taranaki. This plateau, which was uplifted as a whole by crustal forces, is divided by great fractures into earth-blocks. Each of these, during or after uplift, has been tilted, warped, rotated, or otherwise moved to a greater or less degree, and independently of its neighbours. There are two prominent fault-systems, in one of which the fractures strike nearly north and south, and in the other east-north-east. Definite geological evidence of the presence of the faults of the first system was observed at only a few points, and their positions, as shown on the map, were determined largely by the physiography. These faults strike parallel with the general trend of the basal Mesozoic rocks of the district. The evidence for some of the east-north-east faults is good. Thus for three miles west of Te Anga the Marakopa flows through a narrow valley of which the northern side is formed of precipitous hills of Mesozoic rocks, whereas the southern consists of Tertiary limestone. This fault was not traced eastward of Te Anga, but, from the physiography, it probably passes a little south of Taumatatotara Trig. It has a downthrow to the south, in places amounting to over 600 ft. The large earth-block to the north, though doubtless broken by some minor faults, has a general slope to the north and north-west, in which directions it extends to Kawhia Harbour. Five miles south of Te Anga a parallel fault, physiographically well marked, forms the northern boundary of the Herangi earth-block. This block, of which only the northern end enters the district here mapped, is tilted at about 10° to the east, and the uplifted western edge forms the prominent scarp of the Herangi Range, of which the highest peak is Maungamangero (2,656 ft.). The block between the Herangi block and the Marakopa River has a gentle north-westerly slope. The meridional fault or fault-zone bounding the Herangi block on the west continues northward through the Marakopa district. It separates the larger eastern portion of the area, of which the structure has been described above, from a coastal strip averaging three miles in width, of which the structure is unknown.

The northern portion of the area here mapped, consisting of the large earth-block north of the Marakopa River, is drained by streams that flow northward down its slope to Kawhia Harbour. From east to west the principal of these are the Te Toi, Waiharakeke, and Oteki. The basin of the Marakopa River, which drains the bulk of the district, extends eastward to the watershed of the Waipa basin and south-eastward to that of the Mokau. The Marakopa flows west-south-west along or near the fault that passes close to Te Anga. It receives the drainage of the north-west-sloping block to the south by two large tributaries, the Mangapohue and Tawarau, and by several smaller streams—the Tuahaua, Puaroa, and Kairimu. The northern end of the Herangi block drains to the Tawarau



GEOLOGICAL SKETCH-MAP OF THE MARAKOPA DISTRICT.

by way of the Pomarangei and Mangaohae Streams. From the north the Marakopa receives two streams of moderate size only, the Mangahuinga and Mangapapa, which have carved out valleys along meridional fault-zones. The former enters the river at Te Anga, the latter three miles farther west. The run-off from the north-west corner of the district is dammed by shifting sands into a series of shallow lakes, from which the overflow forms Wainui Stream. The south-western corner is drained by the Kiritehere, a stream of moderate size entering the sea about a mile south of the Marakopa.

North of the district the drowned valleys of Kawhia Harbour definitely prove land-depression, but on the western coast the irregularities produced by this depression have now been largely removed by the waves truncating projecting spurs and filling in the inlets. The Marakopa at one time flowed into such an inlet. The river is tidal to a point seven miles from the sea, and in this portion of its course flows through swampy flats for the most part half a mile wide and, especially near the mouth of the river, very little above flood-level. From the junction of the Tawarau near Te Anga (about 90 ft. above sea-level) the river flows at grade through a narrow flood-plain to the western end of the flats above mentioned. Near the Tawarau junction the main stream issues from a gorge that ends in a series of cataracts and a large waterfall about three-quarters of a mile up-stream. Above the waterfall the Marakopa flows at grade in a mature valley, the bottom of which for several miles is between 500 ft. and 600 ft. above the sea. The Tawarau, before joining the Marakopa, flows for four or five miles over many cataracts through a narrow gorge. Above this gorge the valley is wide and mature. The stream-bed at the junction of the Pomarangei and Te Anga – Waitanguru Road is 580 ft. above sea-level. A maturely sculptured upland surface extends eastward from Waitanguru eight or ten miles as far as Mairoa. This surface, which rises gently eastward, is known as the Tawairoa Plateau. The basins of the upper Marakopa and its branches are on this plateau, which passes northward into the Hauturu Plateau. Its surface, though now deeply dissected, once extended much farther west, probably, as is well seen on a distant aspect, almost to the coast. It is a surface developed by long-continued subaerial erosion when the land was some 500 ft. or 600 ft. lower than at present. The southern end of the Tawairoa Plateau is drained by branches of the Mangaotaki, a large tributary of the Mokau River. These cross the Waitanguru – Mairoa Road in shallow mature valleys; but a short distance south of the road (at Waitanguru, less than a mile south of the dairy factory) they descend by series of rapids into gorges entrenched in the old surface.

GENERAL GEOLOGY.

Large areas of the Marakopa district are occupied by Mesozoic rocks, which also must underlie almost the whole district. The observations made are very incomplete, and no sequence could be made out. Immediately to the north of the district along the south shore to Kawhia Harbour and the adjacent coast west towards Albatross Point the following section (in downward sequence) is exposed :—

Conglomerates, grits, and sandstones (5,000 ft.+)	Lower Cretaceous.
Indurated mudstones with minor sandstones and conglomerate bands (10,000 ft.)	Upper Jurassic.
Sandstones, grits, and greywackes with minor conglomerate and shale bands (6,000 ft.)	Lower Jurassic.
Hard greywackes and argillites (6,000 ft.)	Upper Triassic.

The strata of these wide divisions of the Mesozoic rocks differ lithologically, and a well-exposed outcrop, even if fossils are absent, can usually be referred to one or other of them. Thus the siliceous greywackes, hard argillites, and brown sandstones that outcrop along the road south of Marakopa Township and in the valley of the Kiritehere are referred to the Triassic. Hard greywacke containing abundant casts of *Pseudomonotis ochotica* is quarried for road-metal at a point in the Kiritehere Valley due east of Moeatoa Trig.

The green tufaceous sandstones and greywackes, together with thin conglomerates and shales with plant-remains, exposed for several miles along the road east from Moeatoa Post-office belong to the higher beds of the Lower Jurassic. No fossils were observed in this locality, although some occur in these beds in the Kawhia – Albatross Point section.

These beds are succeeded by indurated claystones of great thickness and containing layers of massive sandstone and pebble-beds. They are well exposed from the head of Mangakokopu Creek along the Pomarangei Road to Waitanguru. At several points these beds, which belong to the Upper Jurassic, contain *Inoceramus* and *Belemnites*. Similar fossils occur in the same rocks near Te Anga and on Kawhia Harbour.

Overlying the Upper Jurassic strata without apparent break are a series of well-consolidated conglomerates, grits, and sandstones with minor bands of mudstone.

These beds, which are referred to the Lower Cretaceous, are well exposed on the south side of Kawhia Harbour on either side of the Waiharakeke estuary. They outcrop in the neighbourhood of Te Anga, and the grits and fine conglomerates that form the crest of the Herangi Range near the Pomarangei Road are also referred to this part of the Mesozoic sequence. North of Kawhia Harbour the conglomerates and associated beds extend in a northerly direction for nearly fifty miles. They represent the beach and shallow-water deposits of an ancient coast-line. Since the coarser beds consist in large part of fragments of volcanic rocks, the land from which this material was derived evidently contained large areas covered with eruptive igneous rocks. Fossils are sparingly present, generally in the coarse-textured rocks. Although other forms occur, they usually consist of species of *Aucella*, *Belemnites*, and *Inoceramus*. A small collection was obtained from green-coloured gritty sandstone quarried for road-metal at a point on the Te Anga – Kinohaku Road a mile and a half from Te Anga.

So far as examined the Mesozoic rocks of the Marakopa district have a general easterly dip, so that from the coast inland younger beds are progressively exposed. East of Te Anga the Secondary rocks are concealed beneath those of Tertiary age.

The most prominent Tertiary rocks are the thick beds of limestone which occupy a considerable area in the south-eastern quarter of the area here mapped. From Te Anga and Waitanguru these beds extend almost continuously eastward to Waitomo and Te Kuiti. Smaller areas of limestone occur between Kinohaku and Te Anga, and along the south-east side of Kawhia Harbour. This limestone, which is highly unconformable to the Mesozoic strata, is separated from th m in most localities by thin beds of grit and sandstone. At other points, however, beds of claystone, carbonaceous shale, and coal are present beneath the limestone. Thus near Hauturu, in the north-east corner of the district, 60 ft. of blue calcareous sandy claystone, together with thin beds of brown shale containing a coal-seam, separate the limestone from the Mesozoic rocks.

These Lower Tertiary beds, however, become thinner westward, and from two to six miles from Hauturu the limestone was observed to rest directly, or almost directly, on the basal rocks. Coal, presumably associated with beds of clay and shale of greater or less thickness, is reported to occur at several other points which were not visited (see below). Coal and carbonaceous shale crushed in a fault was observed by the roadside three miles north-east of Waitanguru and three-quarters of a mile north-east of the Pomarangei-Mangaohae junction.

The thicker layers of limestone are often rather sandy, and some bands are decidedly argillaceous. But high-grade stone, which consists in great part of comminuted shells and bryozoans, occurs at many points. It is usually low in the sequence, and in places, where it lies on the Mesozoics, contains fragments of these basal rocks. Near Waitanguru and two miles east of Te Anga are beds of limestone up to 20 ft. thick, formed almost entirely of a thick-shelled oyster (probably *Ostrea wuellerstorfi*). Many of the shells are 12 in. long, 8 in. wide, and 3 in. thick. The full sequence of the calcareous beds is exposed in the neighbourhood of Hauturu, where 300 ft. of limestone, in parts argillaceous, but in general rather sandy, is exposed. No Tertiary beds younger than the limestone are known to outcrop in the district.

South of Albatross Point are high fixed dunes of sand containing much iron-ore. These sands are in places strongly cemented with hydrated oxides of iron. Moving sand-dunes border much of the coast between the Marakopa River and Albatross Point, and south of the latter cover a considerable area. Other Recent deposits are the swamps in the neighbourhood of the Taharoa lakes and the alluvium of the lower valleys of the Marakopa and Kiritehere Streams.

Orangiwhao (996 ft.) and Moeatoa (1,206 ft.) Mountains, respectively at the northern and southen extremities of the coast of the district, are formed of igneous rock, in both cases coarse-grained hornblende andesite approaching a plutonic rock in texture. Orangiwhao is an igneous mass, a mile and a half across, intruded into the Triassic beds of the Mesozoic sequence. Moeatoa is part of a much larger mass that extends south beyond the area mapped, where it forms Whareorino Mountain (2,130 ft.), which, like Orangiwhao, intrudes greywackes of Triassic age.

COAL.

Coal occurs at several points in the district, but only two of these localities were visited. About 20 chains east of Hauturu Post-office and 75 ft. above sea-level a seam $5\frac{1}{2}$ ft. thick and overlain by claystone was worked to a small extent some twenty years ago. The seam outcrops south-eastward some distance along the limestone bluff, and doubtless extends eastward under the limestone, but, without prospecting, no estimate of the amount of coal here present can be given.

Crushed coal associated with carbonaceous shale outcrops beside a road three miles north-east of Waitanguru. The seam, which is at least 2 ft. thick, is involved in a fault. It indicates that coal exists in this locality, and prospecting at the base of the limestone bluffs in the neighbourhood may reveal a workable seam.

Coal or carbonaceous shale is reported to occur (1) on a ridge one and a half miles south-west of Kinohaku; (2) near the top of a ridge four miles east of Marakopa; (3) at the base of a limestone cliff three miles south-west of Te Anga; and (4) beside the Hauturu–Waitomo Road, seven

miles south of Hauturu, on the spur immediately east of the head of Te Toi Stream. The last-mentioned outcrop is reported to be several feet thick.

The following analyses are of samples of coal from some of the above localities :—

	(1.)	(2.)	(3.)
Fixed carbon	35·80	39·20	31·30
Volatile hydrocarbons	36·65	34·60	37·24
Water	21·40	20·50	15·29
Ash	6·15	5·30	16·17
	100·00		100·00
Sulphur	4·40	0·40	4·71
		100·00	

No. 1 : Coal near Hauturu Post-office.
No. 2 : Coal near head of Te Toi Stream. (*Col. Lab. 35th Ann. Rep.*, p. 5, 1902.)
No. 3 : Coal, Mangeao, Waitomo County. (*Dom. Lab. 45th Ann. Rep.*, p. 12, 1912.) This sample was probably from the outcrop north of Waitanguru. The outcrop is about half a mile east of Mangaohae Stream.

IRON-ORE.

In addition to the large amount of iron-ore which forms a considerable proportion of the beach and dune sands of the coast, there is in the district a deposit containing about a million tons of iron-ore. This is situated near Harihari and east of Rototapu, a small lake seven miles north of Marakopa. The deposit is about 50 chains from the coast, and caps a hill of Mesozoic rock. Its base, which is separated from the greywacke by a thin layer of blue clay, is 515 ft. above sea-level. The deposit covers an area of three or four acres, and has a maximum thickness of about 100 ft. Many large roughly rectangular blocks of ore rest on the surface of the main body. The bulk of the ore is compact and has a metallic lustre. On close examination it is seen to consist of closely packed grains of magnetite or ilmenite (averaging about 2 mm. across) cemented with limonite. A few small pebbles of quartz occur. The deposit is horizontally bedded, and is evidently part of an ancient beach sand formed when the land was 500 ft. to 600 ft. lower than at present. The following analyses, by the Dominion Analyst, show its composition to be similar to the ironsands of the existing beaches. It contains, however, only about half the titanium that they do, so that its treatment may be less difficult. It is, moreover, already strongly cemented.

	(1.)	(2.)	(3.)	(4.)	(5.)
Iron (Fe)	59·97	60·42	54·09	52·19	57·12
Titanium dioxide (TiO_2)	5·44	6·91	5·00	10·92	10·60
Phosphorus pentoxide (P_2O_5)	0·48	0·25	n.d.	n.d.	0·36

No. 1 : Iron-ore, strongly cemented, Harihari.
No. 2 : Iron-ore, less compact, Harihari.
No. 3 : Iron-ore from the south side of Kawhia, probably from Harihari. (*Dom. Lab. 53rd Ann. Rep.*, p. 25, 1920.)
No. 4 : Black sand, beach, Waimai Stream, thirteen miles north of Raglan Harbour.
No. 5 : Black sand, Patea breakwater. (*Dom. Lab. 49th Ann. Rep.*, p. 52, 1916.)

REVIEWS AND ABSTRACTS.

The Vegetation of New Zealand, by L. Cockayne, Ph.D., F.R.S., F.L.S., F.N.Z.Inst. W. Engelmann, Leipzig, 1921.

The study of plant ecology, or the relation of plants to their surroundings, has made rapid strides within the last twenty years, during which period the important works of such writers as Schimper, Warming, and Clements have appeared, each giving an impetus to investigations. New Zealand has been well in the forefront in this study, mainly through the work of Dr. Cockayne, whose investigations have been continued uninterruptedly for the last twenty-four years, resulting in a series of important papers on New Zealand plant ecology. The present work, which covers more than the field of his previous writings, may be considered his crowning achievement, and will begin a new period of research in the science, to which, no doubt, Dr. Cockayne himself will continue to contribute. Not only is Dr. Cockayne to be congratulated on producing this epoch-making work, in which an accurate description of the vegetation of New Zealand is placed on record, but to him is due the thanks of botanists, both in New Zealand and beyond, for providing an authoritative account of the flora in its ecological and geographical aspects. The work was brought out under great difficulties, as the completed manuscript was forwarded to Berlin in 1914 before the war broke out, while the volume did not appear until seven years afterwards. It forms No. 14 of *Die Vegetation der Erde*, edited by Professors A. Engler and O. Drude.

The work begins with an outline of the history of botanical investigation in New Zealand, to which is appended a comprehensive bibliography. The physical features and climate of New Zealand are next briefly described. The main portion of the book, that describing the plant formations, is divided into four sections—namely, the vegetation of the sea-coast, lowlands, high mountains, and outlying islands. The sequence is partly geographical, partly biological, and presents an easy method of covering the subject. Preceding each section, or, in the case of the outlying islands, each group of islands, are descriptions of the leading physiognomic species and the biology of the plants. The formations are then described with as much detail as space will allow. A large number of associations are defined, and herein lies a large part of the value of the work as a basis for future workers, and as a record of associations of which many are doomed to extinction under the changed conditions of settlement. The arrangement of describing the ecology of the plants under the above-mentioned headings of " physiognomic species " and " biology of the plants " results in separating descriptions of the associations and their ecology. For instance, the *Poa-Festuca* tussock association is described on page 168, but to learn about its ecology, and even the names of the dominant species, one must turn back to page 107. Statistics is one of the author's strong points, but no attempt is made to evaluate the species in accordance with the frequency of their occurrence. Hence a species counts the same whether it is dominant or rare ; and the figures, for instance, for broad-leaved species do not necessarily show the proportion of broad leaves in the formation, but merely the number of species that possess them.

New Zealand, the author states, was originally covered from north to south with a close mantle of forest, except in those localities where soil conditions were antagonistic or rainfall insufficient. Settlement has reduced the forest to a large extent, though in many places considerable areas still remain in the same state as when visited by the early botanists.

The displacement and replacement of associations and species through the direct interference of man or through competition of introduced species makes an interesting chapter. Indigenous associations have been modified, while new or induced associations of native species have been brought into existence. They include much of the area under bracken-fern and manuka scrub. Regarding the alleged displacement of indigenous by introduced species, Dr. Cockayne states that wherever any part of New Zealand is uninterfered with by man or the animals he has introduced none of the exotics have gained a foothold.

The geographical distribution of plants in New Zealand and their relation to those of other countries is discussed in some detail in the concluding chapters. New Zealand with the adjacent islands is divided into six provinces, which include twenty-two botanical districts. With regard to the origin of the flora, the plants are assigned to various elements, those recognized by the author being the endemic, Palaeozelandic, Australian, Subantarctic, Palaeotropic, and cosmopolitan. The conclusion arrived at is that the flora of New Zealand possesses two distinct main elements, not floristic only but ecological. The first, the more primitive, consists of the Palaeozelandic and Subantarctic elements, having in common the property of being able to endure a fair amount of cold; the second consists of descendants of an ancient Palaeotropic stock. The Australian element is made up largely of Subantarctic and Palaeotropic species, while the characteristic Australian genera are absent.

A brief account of the geological history of the flora concludes the work. It is pointed out that the intense xerophytes in the flora originated when the land area was far greater than at present, and a steppe climate prevailed east of the Southern Alps.

An important feature of the book is the illustrations, numbering ninety-five, most of which are printed on fine art paper and bound at the end of the volume. The vegetation is depicted in all its aspects by clear, sharp views, the bulk of which are from the author's own photographs. On each plate is given a reference to the page where the relative descriptive matter is found. The volume contains 335 pages of text, and is handsomely bound in brown cloth with gold lettering, being altogether a work creditable to both author and publisher. W. R. B. O.

Dominion Museum Monograph No. 1—Some Aspects of Maori Myth and Religion, by Elsdon Best, F.N.Z.Inst. Dominion Museum, 1922.

This monograph now issued by the Dominion Museum, and containing some thirty pages, should be entitled in Maori as a minor "Book of Revelations." It is one more proof that Elsdon Best, unique among ethnographers, can at will take up his residence in the mental dwellinghouse of the Maori and look out through its windows. The shining and often naïve sincerity of the text is exactly that which would show in a priestly adept in Maori esoteric lore, defending his cosmogony and spiritual concepts, and driving home the demonstration that the cults of the Maori have majesty and beauty at least comparable with the medley of opposition *pakeha* faiths. This impression is heightened by the fact that now and again the author seems to feel that he has rounded off a point and cleared away all chance of misconception by quoting an aphorism in pure (and sometimes archaic) Maori. Again, the booklet is hardly likely to fall into the hands of folks who require to be much reminded that the distinction between "myth" and "religion" is a fine one.

The claim that the Maori mind was far along the misty road of abstract thought is supported by a mass of evidence, some of which is startling.

The Maori had a triple distinction where the modern uses the concept "soul," and in one manifestation of this complex idea he approached closely to the Greek conception of "Form." The higher branches of the priesthood cherished a high form of monotheism, naming the Deity or First Cause "Io," "Io the Parent," "Io the Parentless," "Io the Great," "Io of the Hidden Face." There is an intriguing resemblance between this disyllable and "Iahveh" or "Jehovah," and, of course, "Jove." The arbitrament as to which of three deities has furnished the noblest concept is a difficult one, having regard to the case put for the sublime "Io." Another notable revelation is that the Maori "religious" had not progressed to the conception of a hereafter of rewards and punishments. The division of spirit-land lay between the emotion-swayed who continued a glorified earthly existence below the world, and the ultra-pure and rarefied souls who dwelt in a supernal circle of meditation and high thought above the world.

In this brief note there is not space to speak of all the riches in this little treasure-house. The work has the precision of a record of exact fact and profound research. But, more than this, it is coloured by a genius not yet adequately rated. To bring back across the ages the mental processes and the soul-searchings of primitive man is indeed high achievement. For page upon page one hears the tone and rhythm of the Maori tongue dimly sounding in Mr. Best's prose. At times the sonorous lines flash into high poetry; but it is magically the age-old poetry of the Maori, the essential dream-stuff of those gallant old Polynesian voyagers of centuries ago. The monograph is now obtainable through all booksellers or direct from the Dominion Museum, Wellington. The price is one shilling.

O. N. G.

NATURAL-HISTORY NOTE.

Tuatara at Miramar, by Hector R. McLeod.

In the course of search for traces of Maori occupation of the peninsula of Miramar a number of jawbones and other portions of the skeletons of tuatara have from time to time been found. Four jawbones, for instance, were picked up recently in close proximity to several bones of a moa, and other remains—spread over a space of 48 ft. by 60 ft.—which are considered to be those of a cetacean. The age of the latter furnishes a cause of most interesting speculation, for, among the several groups of such, one is 146 ft. above sea-level as measured by survey instruments, and rests apparently on fine-grained wind-blown sand.

As to the present-day existence of tuatara at Miramar, one of the fishermen long resident at the southern shore of Miramar related to me that one morning about the year 1900 he saw, shortly after daybreak, a reptile which he described as very like the iguana which he had seen in Central America. The spot was south of the present golf-links. It rushed, apparently, at him, but in reality to gain the reeds of the lagoon at that spot. A resident of Seatoun Heights told me a few years ago that a tuatara was seen near his residence there. About the year 1908, in the early morning, I saw a tuatara near the top of the range of hills bordering Evans Bay. The spot is about a quarter of a mile north-east of Miramar Wharf. I tried to cut it off from its apparent habitat—a large heap of stone quarried from the side of the hilltop—but the refuge was too close. The tip was too large to move.

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SOIL-PRODUCTIVITY AND THE DISTRIBUTION OF POPULATION IN NORTH AUCKLAND.*

By H. T. FERRAR, M.A., F.G.S., New Zealand Geological Survey.

I. INTRODUCTION.

THE segregation of settlers to certain areas and their absence from other areas was noticed during the course of geological survey work which is being carried out in North Auckland. It soon became evident that there was a close relationship between the distribution of population and the different rock-formations which were being mapped. It is self-evident that in a new country means of access and the fertility of the soil will to a large extent govern the segregation of settlers to those areas which are most productive, but not until a survey has been made does it become manifest that this segregation is caused by the occurrence of certain rocks giving rise to definite soil-types which yield bountiful crops.

The writer is well aware that many factors contribute to the control of soil-productivity,† but with regard to New Zealand in general and North Auckland in particular it would seem that the origin of the soil is the greatest contributing factor. Seven different rock-formations are recognized by the writer‡ as occupying considerable areas in the counties of Hobson, Whangarei, and the Bay of Islands, and each formation gives rise to a distinct type of countryside characterized by its topography, the size of its holdings, its farming practice, and its density of population. In fact, each rock-formation gives rise to a soil-type which conforms to the

---

* A paper read before the Geological Section of the Wellington Philosophical Society, 14th June, 1922. See also "Chemical Aspects of some North Auckland Soils," by W. A. Given, M.A., B.E., on pp. 192–96 of this issue.

† H. T. FERRAR, *Jour. Canterbury A. & P. Soc.*, vol. 3, pp. 28–35, 1915.

‡ H. T. FERRAR, *N.Z. Jour. Sci. & Tech.*, vol. 4, p. 312, 1921.

definition of a soil-formation,* in that it covers a geographically continuous area, and is uniform as regards origin, climatic conditions, texture, vertical section, and composition.

II. Occupations of the Inhabitants.

According to their occupation the inhabitants of North Auckland may be divided into three groups—namely, semi-migratory, urban, and rural. The first influx of Europeans to the district was caused by the demand for kauri-timber. As the forests became exhausted the lumbermen moved to new areas, and but few remained as settlers. The second influx was caused by the demand for kauri-resin, commonly called kauri-gum. The gum-diggers are migratory, and their number has decreased of late, comparatively few remaining to take up land.

The location of the urban population is due to a variety of causes, the chief of which is perhaps accessibility to the sea. Thus the largest town, Whangarei, on the Hatea estuary, was first a timber-exporting port and then a kauri-resin depot. Its chief export at present is dairy-produce. Dargaville is a parallel case. Hikurangi is, and Kamo and Kawakawa were, coal-mining centres, and Russell was a whale-fishers' resort. Tangowahine was, and still is, a sawmilling centre on the navigable Northern Wairoa River. Portland has grown round the cement-works.

The rural inhabitants are chiefly occupied in dairy-farming and cattle-rearing, and only a small part concerns itself with wool-growing. The distribution of the people who gain their livelihood by farming pursuits will now be discussed.

III. The Rock-formations and Density of Rural Population.

The following table, showing density of rural population, has been prepared directly from the geological field-sheets, by computing the areas covered by each rock-formation and counting the number of habitations shown upon each. The field-sheets show most of the houses belonging to people who gain their livelihood by farming; the houses in towns and villages, being shown by conventional signs, are excluded.

Name of Rock-formation.	Nature of Rock.	Area in Square Miles.	Number of Habitations.	Number per Square Mile.	Number per 10 Square Miles.
1. Kaihu Beds ..	Sand-dunes ..	50	5	0·10	1
2. Waipapa Formation ..	Greywackes ..	690	284	0·41	4
3. Onerahi Formation ..	Claystones ..	90	96	1·06	11
4. Part of Kerikeri Series	Acidic volcanic ..	7½	9	1·20	12
5. Whangarei Formation	Sandstone ..	53	98	1·84	18
6. Recent	Swamps and alluvium	70	150	2·14	21
7. Kerikeri Series ..	Basic lavas ..	163	359	2·20	22

A glance at the above table shows at once that there is something inherent in the soils covering these different rock-formations which causes disparity in the distribution of population. The table has been prepared without bias. It is likely that where the density of population is great, as, for instance, on basalt country, houses have been omitted, but where

* See L. J. WILD, *Trans. N.Z. Inst.*, vol. 49, p. 487, 1917.

houses are scarce few will have been overlooked. Had this error been allowed for, the disparity between the figures representing density of population in the above table would have been greater. The boundaries of the areas covered by the several rock-formations were traced for geological purposes. The areas shown above include the whole area covered by the survey, no correction having been made for uninhabited districts such as the infertile portions of the Kerikeri Uplands or the undrained Hikurangi Swamp, which might well have been regarded as abnormalities in the present discussion. Had, say, 30 square miles of the uninhabited Kerikeri Uplands been deducted from the area covered by basalt, and had a deduction of 30 square miles been made from the alluvial area in order to allow for the waterlogged portion of the Hikurangi Swamp, the resulting figures representing density of population would have been increased, and would thereby more nearly represent actual conditions. However, these corrections were not made, the thirty-two field-sheets being taken at random as they came out of a drawer and the computations made automatically.

The table may be checked against the Government Statistician's figures for the year 1920. The total area of the Whangarei and Bay of Islands Counties taken together is 1,847 square miles, and besides Crown and other lands this area includes 2,575 agricultural holdings, some of which, probably one-third, are unoccupied, or occupied only occasionally. On this count there will be some 1,716 habitations, or one to every 1·08 square miles. The table shows one habitation to every 1·12 square miles, which is a sufficiently close agreement.

Means of access do not influence the result, for the different rock-formations are distributed over the whole area. The district thus provides what is virtually a gigantic but natural agricultural "scattered-plot" demonstration.

IV. Characteristics of the different Soil-formations.

1. *Sand-dune Soil.*

An area of some 50 square miles in Hobson County has been found to be covered by consolidated sand-dunes to the exclusion of all other rock-formations. The area specifically referred to lies to the north-west of Dargaville, being bounded on the east by the Kaihu Valley and on the west by the Tasman Sea. The sand-dunes rise to heights of 600 ft. and, being maturely dissected, form rough broken country. On the western side the prevailing moisture-laden winds maintain a scanty growth of pasture, but on the eastern slopes only stunted tea-tree and rushes manage to survive. The few permanent settlers live either near the west coast or have their homesteads on the sandstone spurs overlooking the alluvial flats of the Kaihu Valley. Gum-diggers' camps are scattered over the whole area, but it is seldom that the hutments are occupied permanently. Private individuals occasionally plant tress; the manner of growth of these trees should supply data as to the suitability for afforestization of this soil-formation.

2. *Greywacke Soil.*

The greywacke rocks, mainly altered sandstones or claystones (argillites), cover an area of 690 square miles in Whangarei and Bay of Islands Counties. They form a high, almost mountainous belt of country extending from near the Whangarei Heads to Whakarara, near Whangaroa.

This highland belt, whose peaks sometimes attain heights of 1,500 ft., is close to the east coast of the North Auckland Peninsula, and forms a geographically continuous area which is uniform in respect to origin and climatic conditions. Greywacke country is devoted to grazing, and is characterized by the large size of the holdings and by the paucity of homesteads. The soil which is derived from this rock-formation is thin on the hilltops, but thickens on the spurs and in some of the valleys, hence its productivity depends to some extent upon the land-profiles. Generally it is uniform as regards soil-profile, texture, and composition.

3. *Claystone Soils.*

The greater part of the area covered by the Onerahi Formation which has been mapped by the present survey lies in Whangarei County. The rocks of this formation cover an area of 90 square miles, which is geographically though not stratigraphically a continuous area. Nevertheless the scattered distribution of areas occupied by these rocks makes more apparent their low productive possibilities when compared with neighbouring areas covered by the other rock-formations. The Onerahi claystone formation occupies a belt of lowland country on the inner or south-west side of the greywacke highland belt, and forms diversified hills or smooth treeless downs.

The Onerahi Formation gives rise to two soil-facies similar as regards mode of origin and climatic conditions, but differing in regard to texture, vertical section, and composition. The thin dry soil covering argillaceous limestone domes, such as Mount Tikorangi, forms good pasture, and differs from the claystone soil proper, which for the most part is covered by a growth of fern and scrub. The presence of kauri-stumps and kauri-resin proves that this latter soil-facies once carried a dense growth of timber, which was destroyed before the advent of Europeans to this region.

Large areas of claystone land are uninhabited Government reserves, but where the land is privately held settlers' houses are scarce and the holdings, as a rule, are unoccupied. Claystone areas are locally known as pipeclay country, and are characterized by the stunted vegetation which they carry and by their generally neglected appearance. The State experimental farm at Puwera is situated on claystone soil.

4. *Acidic-volcanic Soil.*

Andesitic tuffs and lava-flows occur as steep isolated hills projecting above the surrounding country. These rocks cover so small an area that the figure for density of population is probably not representative. The white sandy soils derived from these rocks are of low fertility, and are devoted to grazing or overgrown by tea-tree (manuka).

5. *Sandstone Soils.*

Under this heading are grouped all the soils derived from the arenaceous rocks belonging to the Whangarei Formation. These rocks occur as outliers in places overlying the Onerahi claystone formation in the lowland belt mentioned above, and cover 53 square miles of the area which has been surveyed. The sandstone country, which always provides good pasture-land, is well settled, and where the sandstones become calcareous the soil is richer and more closely settled. Hamlets such as Waikiekie and Avoca are situated in areas where the sandstone is calcareous.

It is noteworthy that some of the settlers, who originally owned farms on less productive greywacke or claystone country which they took up under the Land for Settlements Act, have migrated to these more productive districts.

6. *Alluvial Soils.*

All the soils here discussed, except the alluvial, which is a transported soil, are derived from the rock-formations beneath them. The alluvial soils are mixtures of the materials shed from one or more of the several rock-formations found in the district, and their productivity depends more upon their situation with respect to water-channels than upon the other contributing factors. They are always closely settled, and, together with the neighbouring meadow-lands, readily lend themselves to intensive farming.

7. *Basalt Soils.*

In the Whangarei and Bay of Islands Counties basic lava-flows cover 163 square miles of country and form what is locally called "volcanic" land. The lava-flows usually give rise to undulating plains interrupted here and there by isolated scoria cones. The settlers in North Auckland regard these plains as providing the most valuable land in the district, and in consequence volcanic lands are well cultivated and closely settled.

The lavas of the Kerikeri Series give rise to three or more soil-facies depending partly upon the land-profiles or topography of the locality and partly upon the age of the lava-flows. For example, the Kerikeri Uplands are uninhabited, the land being covered by a dense growth of prickly akeake (*Hakea*); the soil is thin, and its surface is strewn with pellets of limonite, from which much of the available plant-food has been removed by a too rapid run-off of rain-water. (For analysis of this soil see B. C. Aston's report in *N.Z. Geological Survey Bulletin No. 8*, p. 6, 1909.) The recent scoriaceous lava-flows, such as occur as Oromahoe, Kawakawa, and elsewhere, are too young to have disintegrated sufficiently to give rise to a deep soil: the soil, however, is rich, but being stony is difficult to cultivate. The soil covering the slopes of the scoria-cones and the undulating lava plains is usually deep and of a dark-red colour. Its texture and hence its capacity for holding water varies slightly, but in other respects it forms a definite and characteristic soil-formation of such fertility as to enduce the segregation of settlers.

V. CONCLUSIONS.

1. It appears evident from the above considerations that the distribution of the rural population in North Auckland is governed by the productivity of the different soils.

2. With one exception, the underlying rock-formations give rise to distinct soil-formations, which differ only as regards origin, texture, and composition.

3. Texture and composition can to some extent be controlled artificially; hence it follows that the best practical method of making a soil-survey in North Auckland should be based on a petrographical classification of the soils.

4. The agricultural treatment best suited to each soil-formation can be determined, and the appropriate fertilizer which will supply deficiencies in the chemical composition of each soil can then be recommended.

CHEMICAL ASPECTS OF SOME NORTH AUCKLAND SOILS.*

By W. A. GIVEN, M.A., B.E., Lecturer in Agriculture, Whangarei High School.

IN the present state of our knowledge, the soils of the North Auckland Peninsula may best be described by classifying them according to geological origin. When examined in this light they are found to comprise the following main types :—

(*a.*) Soils derived from the following sedimentary rocks : (1) Greywacke, (2) claystone, (3) hydraulic limestone, (4) sandstone.

(*b.*) Soils derived from the following igneous rocks : (5) Basalts, (6) rhyolite.

(*c.*) Miscellaneous soils : (7) Alluvium, (8) sand-dunes.

Each of these may now be discussed in correlation with the rock and soil analyses that have been published in various Bulletins of the Geological Survey.

1. *Greywacke Soils.*—From a surface-area point of view greywacke is the most important sedimentary rock in North Auckland. This rock forms the highland country along the east coast between Whangarei and the Bay of Islands. It consists of a fine-grained aggregate of particles of quartz, feldspar, and small amounts of other minerals bound together by a siliceous or clayey cement. According to analyses,† the greywacke contains 63 per cent. of silica and about 5 per cent. of lime ; unfortunately, the amount of the plant-foods potash and phosphoric acid is not given, these compounds being included in the 4 per cent. of the rock not examined by the analyst. Because of the excessive jointing which is characteristic of this rock, it weathers rapidly, and hence is covered with a thick mantle of decomposition products, the upper layer of which is a fine sandy loam. Where this soil remains *in situ* it supports a fairly strong natural vegetation, and where it has been transported and redeposited as an alluvial soil the latter is of good quality, and is an asset to the owner.

Because of the amount of sand it contains the greywacke soil is incoherent, and thus areas covered by it are readily denuded by natural agencies. For this reason deforested areas soon present sharp outlines, and rapidly degenerate from a second- to a fourth-class soil which is deficient in humus and low in retentivity. The greywacke areas of North Auckland present a clear case in which wholesale deforestation may easily be calamitous if not practised advisedly. In order to feed his sheep, man has swept the native forest from much of the greywacke country. Where the cleared country is of low relief the result is a profitable and happy one ; but in the rugged parts how different the story—knife-edge ridges with steep, ever-slipping sides, barren alike of food or beauty ! Before the North Auckland settler puts a match to the virgin forest which still covers some of his

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* See also article by H. T. Ferrar, M.A., F.G.S., "Soil-productivity and the Distribution of Population in North Auckland," pp. 187–91 in this number.

† J. M. BELL and E. DE C. CLARKE, Geology of the Whangaroa Subdivision, *N.Z. Geol. Surv. Bull. No. 8* (N.S.), 1908, p. 43.

rugged country, let him first look about him at the results of similar actions by his predecessors.

2. *Claystone Soils.*—Of the soils derived from sedimentary rocks that formed from claystone is next in importance. This rock was originally a siliceous clay which was accumulated in immense quantities on the floor of an ancient sea. Under the pressure of overburden the clay was compacted into rock which, though hard, is not as resistant as the greywacke. Hence the claystone usually forms low rolling country; only where it has been further hardened by subsequent silicification does it stand out in sharp relief.

The soils derived from it are stiff, colloidal clays containing much fine sand. Because of the prevalence of the fossil resin "kauri-gum" in the claystone areas, these are locally known as "gum-lands." Such is the soil at present under treatment at the Government experimental farm at Puwera, near Whangarei.* The claystone soils are sour and barren, and usually support only stunted vegetation. They are deficient in humus and available plant-food, but evidently contain a useful reserve of food, of which much could be liberated by suitable treatment. A sample of claystone soil was analysed and found to contain†—

	Per Cent.
Organic matter and contained water	5·500
Total nitrogen	0·102
Available plant-food (citric-acid extract)—	
Potash (K_2O)	0·004
Phosphoric acid (P_2O_5)	0·003
Total plant-food (hydrochloric-acid extract)—	
Potash (K_2O)	0·060
Phosphoric acid (P_2O_5)	0·032
Lime (CaO)	0·080

The claystone soils require to be drained and treated with quicklime to deflocculate the clay colloids. This should be followed up by the ploughing-in of suitable soiling-crops to rectify the deficiency in humus. Whether or not these soils can be made capable of supporting permanent pasture, however, remains to be proved.

3. *Hydraulic-limestone Soil.*—The parent rock of this soil is commonly found in or adjacent to claystone areas. It consists of a calcareous mudstone containing 40–80 per cent. of carbonate of lime and 15–30 per cent. of silica.‡ This rock readily breaks down to a fine soil because of removal of the calcareous cement in solution in surface waters—a process greatly aided by the many joints in the rock. Thus, although derived from a limestone, this soil may yet be deficient in lime. Where still forested it supports a strong growth of mixed bush, and where cleared it seems to be capable of supporting a permanent, though thin, pasture.

4. *Sandstone Soils.*—There are, in North Auckland, a number of sandstones all of which have been formed in the same way. In places they form hills up to 1,000 ft. in height, but nowhere do they make country so rugged as to be unworkable. These sandstones are alike in that they

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* An instructive account of the operations and results of experiments at Puwera will be found in the *New Zealand Journal of Agriculture* for May, 1921.

† BELL and FRASER, *op. cit.*, p. 8. (Analyst, B. C. Aston.)

‡ Many analyses are given in *N.Z. Geol. Surv. Bull. No. 22*, The Limestone and Phosphate Resources of New Zealand, 1919, pp. 53–55, 57, 59, 61, 63, and 64.

consist mainly of rounded grains of quartz cemented into a compact mass: they differ in the nature of the cementing-material. The sandstone in which silica is the cementing-medium weathers but slowly, and hence the soil on it is thin; further, being composed mainly of silica, the soil contains practically no plant-food, and is sour and barren. Those sandstones in which the binding-matter consists of clay, carbonate of lime, or glauconite, weather readily, and hence are covered with thick mantles of decomposition products. These soils are of fair quality, and contain a moderate amount of plant-food; they quickly become sour, however, where the drainage is poor. Those of the glauconitic and clayey sandstones maintain a thin pasture of native grass; the soil of the calcareous sandstone is much better, and is usually found to be covered with strong, healthy pasture.

With two minor exceptions this appears to exhaust the soil-types formed from sedimentary rocks in North Auckland. The exceptions are the insignificant amounts of soil formed by disintegration of scattered deposits of quartzite and crystalline limestone. The former rock consist entirely of silica, and hence forms practically no soil; the latter, though it leaves a rich, fine soil, is of little importance as a soil-former in North Auckland because it occurs in such small amounts.

In sharp contrast to the soils of the sedimentary rocks are those derived from the various igneous rocks of the peninsula. Attention will be confined in these notes to the soils derived from rhyolite and from the basalts. The writer is aware of the presence of other igneous rocks in North Auckland, but has omitted these because they form precipitous country rather than areas of arable land.

5. *Basalt Soils.*—These are the soils which form the "volcanic land" of the farmer. The underlying basalt may be one or another of two flows which have evidently been erupted at different periods. The older flow consists of a compact, well-crystallized basalt; adjacent to and sometimes resting on this may be found a younger scoriaceous flow of rock of similar composition. The older, compact lava is usually found to be covered with a good thickness of warm, brown soil; the younger flow, however, especially where very scoriaceous, is often covered only by a thin layer of dry, stony soil. Here differences in the texture and thickness of the two soils arise from differences in the texture of the parent rocks. The older flow, being compact, decomposes slowly, but the products of decomposition are retained on its surface; the younger flow, being scoriaceous, decomposes rapidly, but the resultant soil soon works down through interstices and is lost. In some places the younger flow appears to have been more liquid at the time of eruption; at other points it seems to have been ejected as dust rather than as lava. Both these variants give a better soil (from a textural point of view) than the normal scoriaceous form.

Analyses of the older basalt show it to contain about 10 per cent. of lime and between 1 and 2 per cent. of potash*; the younger rock is probably of similar composition. Theoretically, these basalts should produce better soils — more retentive and richer in plant-food — than those actually found; for, although these rocks contain marked amounts of lime and potash, the soils are nevertheless deficient in both these compounds: they are responsive to potash and phosphate fertilizers, particularly the latter. This deficiency—as well as the low water-holding capacity of these soils—is the result of excessive subsoil drainage which characterizes the

* BELL and CLARKE, *op. cit.*, p. 71.

scoriaceous form of the rock. The soils are thereby leached almost barren of available plant-food; in addition, they are parched in dry weather. (Note: The fact that the volcanic soils of North Auckland support a luxuriant natural vegetation is no counter-argument, for the forest-trees not only prevent surface evaporation of soil-water, but they also keep up a replenishing supply of humus, which in itself is highly retentive.) The rational treatment for such soils is the addition of clay and humus (this by green-manuring) before attempting to make use of soluble fertilizers.

Curiously enough, the analyses above referred to show no phosphorus in the rock—an unusual feature in a basalt. This element is present, however in the basalt of other parts of North Auckland, as is shown in the following analysis of a sample of "ironstone soil" (recorded on page 7 of the same *Bulletin*):—

	Per Cent.
Organic matter (mostly roots) and combined water ..	17·560
Total nitrogen	0·232
Available food (citric-acid extract)—	
Potash	0·006
Phosphoric acid	0·003
Total food (hydrochloric-acid extract)—	
Potash	0·080
Phosphoric acid	0·480
Lime	0·150

(Note: "Ironstone soil" is a basalt soil containing many pebbles and nodules of limonite.)

6. *Rhyolite Soils.*—The rhyolitic rocks—Parahaki and Kamo Mountains, near Whangarei, are examples—contrast strongly with the basalts just described. They contain about 70 per cent. of silica, 5 per cent. of potash, and very little lime, whereas the basalts contain only 50 per cent. of silica, but 2 per cent. of potash and as much as 8 per cent. of lime. The rhyolites are capable of developing into good soils, which, however, are markedly deficient in phosphorus. These soils do not suffer from leaching, as do those of the basalts.

7. *Alluvial Soils.*—The soils of the fresh-water river and stream flats vary in composition according to the nature of the rocks from which they have been derived. Those that have been derived from greywacke, hydraulic or crystalline limestone, or from the basalts, are highly fertile; those that have been derived from claystone or sandstone, however, tend to acidity unless adequately drained. Whether the silts now being accumulated on tidal estuarine flats will ultimately furnish a soil-type remains to be seen. Probably they will, for reasons which are clearly shown in the following analysis of soil from a dry mangrove flat at Whangaroa.*

	Per Cent.
Organic matter and combined water	7·300
Total nitrogen	0·150
Available food (citric-acid extract)—	
Potash	0·038
Phosphoric acid	0·035
Total food (hydrochloric-acid extract)—	
Potash	0·610
Phosphoric acid	0·100
Lime	0·400

* BELL and FRASER, *op. cit.*, p. 10, 1909. (Analyst, B. C. Aston.)

Such a soil, if properly drained, would be fertile for cruciferous crops (such as mangolds and cabbages) which thrive in salt-laden soils.

8. *Sand-dunes.*—Ancient and modern sand-dunes cover considerable areas near Waipu, at Dargaville, and again in the northernmost part of the peninsula. Such sand-masses are composed almost entirely of silica, and hence form but little true soil. They are covered by a stunted growth of native rushes and similar plants, which are able to eke out in the moist portions of these areas. Thus, though sand-dunes cover much of the North Auckland Peninsula, they are of no agricultural importance.

9. If there is any general conclusion to be drawn from the foregoing it is that, apart from the very necessary incorporation of humus in the soil, the land should be toned up by the application of artificial fertilizers before cropping has exhausted it of its plant-food. Particularly is this the case with the high-silica soils, for once depleted of plant-food such soils have no reserve and become practically useless.

A SYNONYMIC REFERENCE LIST OF NEW ZEALAND COCCIDAE.

By J. G. MYERS, F.E.S., Biology Division, Department of Agriculture.

THIS list has been compiled in the hope that the long-existing want of a convenient catalogue of New Zealand scale insects, incorporating the many nomenclatorial and classificatory changes which intensive study has made in the family since Maskell's time, may be in some measure satisfied. All the species, with the supposed country of origin of foreign species, are included whenever a definite record can be obtained, so that the list will at least form a convenient basis for the future work of Dominion coccidologists.

The Maskell collection, which has now been returned to this country, was lent by the Department of Agriculture to the United States Bureau of Entomology for extended study, the results of which are now in course of publication in America, commencing with "A Redescription of the Type Species of the Genera described by Maskell or based on Species originally described by him," by Harold and Emily Morrison. The first part of the manuscript, dealing with the Monophlebinae and Margarodinae, has helped me in the listing of these two subfamilies.

The work of Maskell extended over the period from 1879 to 1897, and was of world-wide scope. Since his death Coccid study has been continued in this country by Brittin in three papers published in 1915 and 1916, and by scattered notes on the more important economic species by officers in the reports of the Department of Agriculture.

For two of the records I am indebted to Professor G. F. Ferris, of Stanford University, California, and to Mr. David Miller for general help and advice.

To avoid the repetition of frequent references the following abbreviations have been used :—

T = *Transactions of the New Zealand Institute.*
S = W. M. MASKELL, *An Account of New Zealand Scale Insects*, 1887.

Of the 115 species recorded, 84 are apparently confined to New Zealand; while of the remaining 31, 4 may be referred with more or less certainty to Australia, and 27 are now practically cosmopolitan.

Subfamily 1. MONOPHLEBINAE.

Icerya purchasi Mask. Australia ? T., vol. 11, p. 221, 1879 ; T., vol. 16, p. 140, 1884 ; T., vol. 17, p. 30, 1885 ; T., vol. 19, p. 45, 1887 ; S., p. 104.

Subfamily 2. MARGARODINAE.

Coelostomidia zealandica (Mask.). Cockerell, *Entom.*, vol. 35, pp. 114, 258, 1902.
Coelstoma zealandicum Mask., T., vol. 12, p. 294, 1880 ; T., vol. 14, p. 226, 1882 ; T., vol. 16, p. 141, 1884 ; S., p. 107.

Coelostomidia wairoense (Mask.). Cockerell, *loc. cit.*, 1902.
Coelostoma wairoense Mask., T., vol. 16, p. 141, 1884 ; S., p. 109.

Coelostomidia compressa (Mask.). Cockerell, *loc. cit.*, 1902.
Coelostoma compressum Mask., T., vol. 24, p. 45, 1892.

Coelostomidia pilosa (Mask.). Cockerell, *loc. cit.*, 1902.
Coelostoma pilosum Mask., T., vol. 23, p. 29, 1891 ; T., vol. 24, p. 49, 1892.

Ultracoelostoma assimile (Mask.). Cockerell, *loc. cit.*, 1902.
Coelostoma assimile Mask., T., vol. 22, p. 153, 1890 ; T., vol. 23, p. 30, 1891.

Subfamily 3. PHENACOLEACHIINAE.

Phenacoleachia zealandica (Mask.). Cockerell, *Entom.*, vol. 35, p. 260, 1902.
Leachia zealandica Mask., T., vol. 23, p. 26, 1891.

Subfamily 4. DACTYLOPIINAE.

Asterolecanium variolosum Ratz. Palaearctic.
Asterolecanium quercicola Sign. et Auctt.
Coccus variolosus Ratz., *Tharander Jahrb.*, vol. 20, p. 187, 1870.
Planchonia fimbriata (Boy.) Mask., T., vol. 27, p. 62, 1895.
Planchonia quercicola (Bouché) Mask., T., vol. 28, p. 396, 1896.
Asterolecanium variolosum (Ratz.) Brain, *Bull. Ent. Res.*, vol. 10, p. 110, 1920

Asterolecanium epacridis (Mask.).
Planchonia epacridis, T., vol. 14, p. 224, 1882 ; S., p. 91.

Solenococcus corokiae (Mask.).
Solenophora corokiae Mask., T., vol. 22, p. 141, 1890 ; T., vol. 23, p. 18, 1891.

Solenococcus fagi (Mask.).
Solenophora fagi, T., vol. 22, p. 139, 1890.

Rhizococcus celmisiae Mask., T., vol. 16, p. 135, 1884 ; S., p. 96.

Rhizococcus fossor Mask., T., vol. 16, p. 136, 1884 ; S., p. 97.

Rhizococcus intermedius Mask., T., vol. 23, p. 19, 1891.

Rhizococcus maculatus Mask., T., vol. 22, p. 144, 1890.

Rhizococcus pulchellus Mask., T., vol. 22, p. 143, 1890.

Rhizococcus fimbriatus (Brittin).
Rhizococcus fimbriatus Green, *Bull. Ent. Res.*, vol. 7, p. 51, 1916.
Scutare fimbriata Brit., T., vol. 47, p. 158, 1915.

Rhizococcus totarae Mask., T., vol. 22, p. 142, 1890; T., vol. 23, p. 19, 1891.

Gossyparia cavellii Mask., T., vol. 22, p. 147, 1890.

Eriococcus araucariae Mask. Australia? T., vol. 11, p. 218, 1879; T., vol. 16, p. 134, 1884; S., p. 93.
Rhizococcus araucariae Comst., *Rept. U.S. Dept. Ag.*, p. 339, 1881.

Eriococcus coriaceus Mask. Australia. T., vol. 25, p. 229, 1893.

Eriococcus danthoniae Mask., T., vol. 23, p. 21, 1891.

Eriococcus fagicorticis Mask., T., vol. 24, p. 27, 1892.

Eriococcus hoheriae Mask., T., vol. 12, p. 298, 1880; S., p. 93.

Eriococcus multispinus Mask.
Acanthococcus multispinus Mask., T., vol. 11, p. 217, 1879; T., vol. 12, p. 292, 1880; T., vol. 17, p. 29, 1885.
Eriococcus multispinus Mask., S., p. 94. Brittin, T., vol. 48, p. 423, 1916.

Eriococcus pallidus Mask., T., vol. 17, p. 29, 1885; S., p. 95.
Eriococcus pallidus Brittin, T., vol. 48, p. 423, 1916.

Eriococcus phyllocladi Mask., T., vol. 24, p. 25, 1892.

Eriococcus raithbyi Mask., T., vol. 22, p. 145, 1890.

Phenacoccus asteliae (Mask.).
Pseudococcus asteliae Mask., T., vol. 16, p. 139, 1884; S., p. 102.

Pseudococcus adonidum (Linn.). Cosmopolitan.
Dactylopius adonidum Mask., T., vol. 22, p. 150, 1890.
Pseudococcus longispinus Auctt.

Pseudococcus alpinus (Mask.).
Dactylopius alpinus, T., vol. 16, p. 138, 1884; S., p. 99.

Pseudococcus arecae (Mask.).
Dactylopius arecae Mask., T., vol. 22, p. 150, 1890; T., vol. 25, p. 231, 1893.

Pseudococcus aurilanatus (Mask.). (Origin?)
Dactylopius aurilanatus Mask., T., vol. 22, p. 151, 1890.

Pseudococcus calceolariae (Mask.).
Dactylopius calceolariae Mask., T., vol. 11, p. 218, 1879; T., vol. 16, p. 138, 1884; S., p. 100.

Pseudococcus glaucus (Mask.).
Dactylopius glaucus Mask., T., vol. 11, p. 219, 1879; T., vol. 17, p. 30, 1885; S., p. 100.

Pseudococcus iceryoides (Mask.).
Dactylopius iceryoides Mask., T., vol. 24, p. 33, 1892.

Pseudococcus obtectus (Mask.).
Dactylopius obtectus, T., vol. 22, p. 152, 1890.

Pseudococcus poae (Mask.).
Dactylopius poae, T., vol. 11, p. 220, 1879; S., p. 101. Brittin, T., vol. 48, p. 424, 1916.

Pseudococcus sexaspinus Brittin, T., vol. 47, p. 154, 1915.

Pseudococcus cockaynei Brittin, T., vol. 47, p. 153, 1915.

Pseudococcus oamaruensis Brittin, T., vol. 47, p. 153, 1915.

Pseudococcus maritimus (Ehrhorn). America.
Dactylopius maritimus Ehrh., *Can. Ent.*, vol. 32, p. 315, 1900.
Pseudococcus obscurus Essig., *Pomona Coll. Journ. Ent.*, vol. 1, p. 43, 1909.
Pseudococcus bakeri Essig., *loc. cit.*, vol. 2, p. 334, 1909.
Pseudococcus omnivorae Holl., *Ann. Ent. Soc. Am.*, vol. 10, p. 271, 1917.

Pseudococcus comstocki (Kuwana). Japan.
Dactylopius comstocki Kuwana, *Proc. Cal. Acad. Sci.* (3), vol. 3, p. 52, 1902.

Ripersia fagi Mask., T., vol. 23, p. 24, 1891.

Ripersia formicicola Mask., T., vol. 24, p. 38, 1892.

Ripersia rumicis Mask., T., vol. 24, p. 37, 1892.

Ripersia globatus Brittin, T., vol. 47, p. 155, 1915.

Ripersia occultum Brittin, T., vol. 47, p. 155, 1915.

Kuwanina parva (Mask.). Japan.

Kuwanina parva Green, *Bull. Ent. Res.*, vol. 7, p. 52, 1916.
Sphaerococcus parvus Mask., T., vol. 30, p. 247, 1898.
Cryptococcus nudata Brittin, T., vol. 47, p. 160, 1915.

Subfamily 5. Coccinae.

Eriochiton hispidus Mask., T., vol. 19, p. 47, 1887 ; S., p. 84.

Eriochiton spinosus Mask.

Ctenochiton spinosus Mask., T., vol. 11, p. 212, 1879 ; T., vol. 12, p. 292, 1880 ; T., vol. 14, p. 218, 1882 ; T., vol. 17, p. 25, 1885.
Eriochiton spinosus Mask., S., p. 86. Brittin, T., vol. 48, p. 425, 1916.
Lecanium armatus Brittin, T., vol. 47, p. 152, 1915.

Pulvinaria camellicola Sign. Europe. *Ann. Soc. Ent. France*, 1873, p. 32. Mask., T., vol. 11, p. 207, 1879 ; S., p. 83.

Lecanochiton metrosideri Mask., T., vol. 14, p. 222, 1882 ; T., vol. 16, p. 129, 1884 ; S., p. 64.

Lecanochiton minor Mask., T., vol. 23, p. 12, 1891.

Ctenochiton dacrydii Mask., T., vol. 24, p. 18, 1892.

Ctenochiton depressus Mask., T., vol. 16, p. 132, 1884 ; S., p. 66.

Ctenochiton elaeocarpi Mask., T., vol. 17, p. 26, 1885 ; S., p. 67.

Ctenochiton elongatus Mask., T., vol. 11, p. 212, 1879 ; S., p. 68.

Ctenochiton flavus Mask., T., vol. 16, p. 130, 1884 ; vol. 17, p. 26, 1885 ; S., p. 68.

Ctenochiton fuscus Mask., T., vol. 16, p. 131, 1884 ; S., p. 70.

Ctenochiton hymenantherae Mask., T., vol. 17, p. 25, 1885 ; S., p. 71.

Ctenochiton perforatus Mask., T., vol. 11, p. 280, 1879 ; T., vol. 16, p. 130, 1884 ; S., p. 72.

Ctenochiton piperis Mask., T., vol. 14, p. 218, 1882 ; T., vol. 17, p. 25, 1885 ; S., p. 73.

Ctenochiton viridis Mask., T., vol. 11, p. 211, 1879 ; T., vol. 17, p. 24, 1885 ; S., p. 74.

Inglisia patella Mask., T., vol. 11, p. 213, 1879 ; T., vol. 14, p. 219, 1882 ; S., p. 78.

Inglisia fagi Mask., T., vol. 23, p. 13, 1891.

Inglisia inconspicua Mask., T., vol. 24, p. 19, 1892.

Inglisia leptospermi Mask., T., vol. 14, p. 220, 1882 ; T., vol. 17, p. 27, 1885 ; S., p. 75.

Inglisia ornata Mask., T., vol. 17, p. 27, 1885 ; S., p. 76.

Coccus longulus (Doug.). Cosmopolitan.

Lecanium longulum Mask., T., vol. 29, p. 310, 1897.

Coccus hesperidum (Linn.). Cosmopolitan.

Lecanium hesperidum Mask., T., vol. 11, p. 205, 1879 ; S., p. 80.

Coccus maculatus (Sign.). Europe ?

Lecanium maculatum Sign., *Ann. Soc. Ent. France*, 1873, p. 400. Mask., T., vol. 11, p. 207, 1879 ; S., p. 81.

Eulecanium corni (Bouché). Cosmopolitan.

Lecanium corni Bouché, *Stett. Ent. Zeit.*, vol. 5, p. 298, 1844.
Lecanium mori Sign., *Ann. Soc. Ent. France*, 1873, p. 407. Mask., T., vol. 17, p. 29, 1885 ; S., p. 82.
Lecanium ribis Fitch, *Trans. N. York Agr. Soc.*, 1856. Mask., T., vol. 23, p. 16, 1891 ; T., vol. 24, p. 22. 1892.

Saissetia oleae (Bernard). Tropics and subtropics.
Chermes oleae Bernard, *Mem. d'Hist. Nat. Acad. Marseilles*, 1872, p. 108.
Lecanium oleae Mask., T., vol. 17, p. 28, 1885 ; S., p. 82.

Saissetia depressa (Targ.). Almost cosmopolitan.
Lecanium depressum (Targ.). Mask., T., vol. 11, p. 206, 1879 ; S., p. 79.

Saissetia hemisphaerica (Targ.). Almost cosmopolitan.
Lecanium hemisphaericum Mask., T., vol. 17, p. 29, 1885 ; S., p. 80.
Lecanium hibernaculorum (Targ.). Mask., T., vol. 11, p. 207, 1879 ; S., p. 81.

Saissetia cassiniae (Mask.).
Lecanium cassiniae Mask., T., vol. 23, p. 15, 1891.

Subfamily 6. DIASPINAE.

Chionaspis citri Comstock. Now almost cosmopolitan. *2nd Rept. Dept. Ent. Cornell University*, 1883. Mask., T., vol. 17, p. 23, 1885 ; S., p. 54.
Chionaspis euonymi Comst. (part), *Rep. U.S. Dept. Agr.*, 1880, p. 313.

Chionaspis dubia Mask., T., vol. 14, p. 216, 1882 ; S., p. 54.

Chionaspis dysoxyli Mask., T., vol. 17, p. 22, 1885 ; S., p. 55.

Hemichionaspis minor (Mask.), *Chionaspis minor*, T., vol. 17, p. 23, 1885 ; S., p. 56.

Diaspis boisduvalii Sign. Almost cosmoplitan. *Ann. Soc. Ent. France*, 1868, p. 432. Mask., T., vol. 11, p. 200, 1879 ; T., vol. 17, p. 23, 1885 ; S., p. 46.

Aulacaspis rosae (Bouché). Cosmopolitan.
Aspidiotus rosae Bouché, *Naturg. Ins.*, vol. 14, 1834.
Diaspis rosae (Bouché). Mask., T., vol. 11, p. 201, 1879 ; S., p. 47.

Poliaspis media Mask., T., vol. 12, p. 293, 1880 ; S., p. 57.

Poliaspis argentosis Brittin, T., vol. 47, p. 150, 1915.

Leucaspis gigas (Mask.).
Diaspis gigas Mask., T., vol. 11, p. 201, 1879.
Fiorinia asteliae Mask., T., vol. 12, p. 292, 1880 ; T., vol. 14, p. 217, 1882 ; T., vol. 17, p. 24, 1885 ; S., p. 58.
Uhleria gigas Comst., *2nd Ent. Rep. Cornell Univ.*, 1883, p. 111.
Fiorinia morrisii Brittin, T., vol. 47, p. 149, 1915.
Leucaspis gigas (Mask.). Lindinger, *Jahrb, Hamb. Wiss. Anst.*, vol. 23, p. 57, 1906. Green, *Trans. Ent. Soc. Lond.*, 1914, p. 460 ; *Bull. Ent. Res.*, vol. 7, p. 51, 1916.

Leucaspis maskelli (Brittin).
Fiorinia maskelli Brittin, T., vol. 47, p. 157, 1915.
Leucaspis maskelli (Brittin). Green, *Bull. Ent. Res.*, vol. 7, p. 51, 1916.

Leucaspis cordylinidis (Mask.).
Leucaspis cordylinidis Green, *Trans. Ent. Soc. Lond.*, 1914, p. 460.
Mytilaspis cordylinidis Mask., T., vol. 11, p. 195, 1879 ; S., p. 48.

Leucaspis stricta (Mask.).
Leucaspis stricta Leonardi, *Ann. di Agr.*, vol. 6, 1906. Lindinger, *Jahrb. Hamb. Wiss. Anst.*, vol. 23, p. 57, 1906. Green, *Trans. Ent. Soc. Lond.*, 1914, p. 462.
Fiorinia stricta Mask., T., vol. 16, p. 124, 1884 ; T., vol. 17, p. 24, 1885 ; S., p. 60.

Leucaspis japonica Ckll. Japan ?
Leucaspis japonica Lindinger, *Jahrb. Hamb. Wiss. Aust.*, vol. 23, 1906. (Synonymized with some doubt.)
Mytilaspis drimydis Mask., T., vol. 11, p. 196, 1879; S., p. 49. Brittin, T., vol. 48, p. 425, 1916.

Fiorinia grossulariae Mask., T., vol. 16, p. 123, 1884 ; S., p. 59.

Fiorinia minima Mask., T., vol. 16, p. 122, 1884 ; S., p. 59.

Odonaspis ? leptocarpi Brittin, T., vol. 48, p. 425, 1916.

Aspidiotus atherospermae Mask., T., vol. 11, p. 198, 1879 ; T., vol. 27, p. 1, 1895 ; S., p. 40.

Aspidiotus carpodeti Mask., T., vol. 17, p. 21, 1885 ; S., p. 41.

Aspidiotus corokiae Mask., T., vol. 23, p. 2, 1891.

Aspidiotua dysoxyli Mask., T., vol. 11, p. 198, 1879 ; S., p. 43.

Aspidiotus hederae (Vallot). Almost cosmopolitan.

Chermes hederae Vallot, *Mem. Acad. Sci. Dijon*, 1829, p. 30.
Aspidiotus nerii (Bouché). Mask., T., vol. 14, p. 217, 1882 ; S., p. 44.
Aspidiotus palmarum Burm., *Handl. Ent.*, vol. 2, p. 69, 1835.
Aspidiotus limonii Sign., *Ann. Soc. Ent. France* (4), vol. 9, p. 125, 1869.

Aspidiotus perniciosus Comstock. Almost cosmopolitan. *Rept. U.S. Dept. Agr.*, 1881, p. 304.

Aonidia fusca Mask., T., vol. 27, p. 43, 1895.

Aspidiotus rapax Comstock. Almost cosmopolitan. *Rep. U.S. Dept. Agr.* 1881, p. 307.

Aspidiotus camelliae Sign., *Ann. Soc. Ent. France* (4), vol. 9, p. 117, 1869. Mask., T., vol. 11, p. 200, 1879 ; T., vol. 17, p. 21, 1885 ; S., p. 41.
Diaspis santali Mask., T., vol. 16, p. 122, 1884 ; S., p. 47.

Aspidiotus sophorae Mask., T., vol. 16, p. 121, 1884 ; S., p. 45.

? Aspidiotus budleiae Sign. Cosmopolitan ? *Ann. Soc. Ent. France*, 1868, p. 115. Mask., T., vol. 11, p. 198, 1879.

? Aspidiotus epidendri Bouché. Cosmopolitan ? Sign., *Ann. Soc. Ent. France*, 1868, p. 121. Mask., T., vol. 11, p. 197, 1879 ; S., p. 44.

Chrysomphalus aurantii (Mask.). Almost cosmopolitan.

Aspidiotus aurantii Mask., T., vol. 11, p. 199, 1879 ; S., p. 42.
Aspidiotus coccineus Genn., *Ann. Soc. Ent. France* (6), vol. 1, p. 189, 1881.
Aspidiotus citri Comst., *Can. Ent.*, vol. 13, p. 8, 1881.

Chrysomphalus rossi (Mask.). Australia.

Aspidiotus rossi Mask., T., vol. 24, p. 11, 1892 (original description) ; T., vol. 23, p. 3, 1891 ; T., vol. 25, p. 207, 1893 ; T., vol. 29, p. 296, 1897.

Lepidosaphes beckii (Newm.). Almost cosmopolitan.

Coccus beckii Newm., *The Entomologist*, vol. 4, p. 217, 1869.
Aspidiotus citricola Pack., *Guide to Study of Insects*, p. 527, 1870. Comst., *Rep. U.S. Dept. Agr.*, 1880, p. 321.
Mytilaspis citricola Mask., T., vol. 22, p. 135, 1890 ; T., vol. 27, p. 48, 1895.
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FOSSIL PEARLS IN NEW ZEALAND.

By J. MARWICK, M.A., New Zealand Geological Survey.

As far as the writer is aware, the occurrence of pearls in a fossil state has not been recorded hitherto. Consequently the two examples cited below seem worthy of notice.

The first specimen was found by that great collector, the late Mr. Augustus Hamilton, in the fossiliferous marine clays below the limestone at Petane, Hawke's Bay. It is now in the collection of his son, Mr. H. Hamilton, of the Dominion Museum. This pearl, a perfect sphere of two millimetres diameter, is embedded in a piece of the matrix, and, although slightly dimmed, is still of good lustre. The only other fossil remains on the slab of clay are small fragments of a prismatic shell, probably *Atrina zelandica* (Gray).

Melina zealandica Suter.

The second specimen, also from Hawke's Bay, is in the possession of Mr. John Teschmaker, of Green Hill, Mangatahi. It was collected by him from the blue, sandy clays outcropping on his property in the bed of Okauawa Creek. This example is a great deal larger than the first one, being some 5 millimetres in diameter; it is, however, of somewhat irregular shape and not of good lustre. The pearl was embedded in the clay directly under a valve of the large mollusc *Melina zealandica* Suter. In all probability both gems owe their origin to this species, for the Petane and the Mangatahi clays belong to the same formation of which the *Melina*, now extinct, is a characteristic fossil.

Many people attribute the origin of pearls to the oyster; but although several genera of molluscs have provided inferior pearls and pearly structures,* the great pearl-producer, *Margaritifera*, which supplies the bulk of these gems, is not an oyster at all. It belongs to the family Aviculidae, and it is important to note that in a wide sense *Melina zealandica* also comes under this family.

The formation in which these interesting fossils occur is of Upper or Middle Pliocene age; and, although an exact estimate cannot be made, the length of time that has elapsed since their burial must be in the neighbourhood of three million years.†

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* W. J. DAKIN, *Pearls*, Cambridge University Press, 1913.
† J. BARRELL, *Bull. Geol. Soc. America*, 1917, vol. 28, p. 884.

MAORI WOODCRAFT.

A Peculiar Device for taking Small Birds.

By ELSDON BEST, Dominion Museum.

Illustration by J. McDONALD.

THE Maori of pre-European days possessed many different devices for taking birds, and the *pae* method was a common one. The illustration given is that of a *pae pihipihi*, as manipulated in taking the blight-bird (*pihipihi*), a diminutive Australian bird that appeared in the South Island about the middle of last century. It is said to have crossed Cook Strait

in 1856, and in after-years became very numerous in all districts. The Maori was not slow to include it in his food-supplies, small though the creature be. I have seen them taken in thousands, and preserved in fat for future use. The Tuhoe folk preserve them nowadays in kerosene-tins. The little birds are not cleaned, and are not too carefully plucked. They

are cooked, or partially cooked, packed in the tins, and melted fat is poured over them. When partaking of this luxury you pluck a bird from the mass of fat and eat it as it is, including bones and a fair share of feathers.

The *pae* apparatus is of simple construction. A stout, long rod is thrust firmly into the ground, and its upper end is bent over. From the bent-down end to the vertical unbent part of the rod a cord is secured. This is often in a more horizontal position than is shown in the illustration. This bow-string cord is the *tau maimoa*, from which are suspended by their beaks the first few birds taken alive. The fluttering endeavours to escape made by these captives serves to attract more birds, which are also lured by the fowler by means of a chirping call. This call is made either with the lips or by means of a call-leaf (*pepe*). The birds so attracted settle on the *pae*, or bent upper portion of the rod. The fowler sits in a rude shelter of branches or tree-fern fronds, holding in his right hand a long, slight rod which rests lightly against the *pae* on which the birds alight. When the operator wishes to strike one or more birds on the *pae* he runs the striking-rod (*hauhau*, or *ta*) rapidly along the *pae*, so knocking off and crippling any bird seated on it. A short piece of string is tied to the *tau maimoa*, called the *takiri*, and if the decoy birds cease fluttering the operator pulls this cord and starts them struggling again. Now, if the *tau maimoa* were left in a straight line the sweep of the *ta* would kill the decoy birds, hence a short piece of stick is lashed to the vertical rod, and to its outer end is hitched the *tau maimoa*, bringing it out of the line of fire, as it were. Until such time as he has secured decoy birds, the fowler suspends a few leaves, such as those of the *mako*, from the *tau maimoa*, and he agitates these by pulling the *takiri*. The man seen operating the *pae* in the illustrations is Apirana Tukairangi, of Taupo. The apparatus was erected near the old Operiki *pa*, on the Whanganui River.

Many species of birds, including the *tui*, or *koko*, were formerly taken by this means, but it now seems to be employed only for the blight-bird.

THE TARO (COLOCASIA ANTIQUORUM).

By ELSDON BEST, Dominion Museum.

With illustration by J. MCDONALD.

THE *taro* was one of four cultivated food plants introduced into New Zealand in past centuries by the Polynesian settlers. The most highly prized of these products was the *kumara* (*Ipomaea batatas*), and the *taro* came next in importance as a food product. The *kumara* was cultivated as far south as Banks Peninsula in the South Island, but the *taro* was somewhat less hardy, and could not be grown so far south. The cultivation of the yam was confined to the northern part of the North Island, while the *hue*, or gourd, was eatable only in its *kotawa* or immature stage of growth, as we use vegetable marrow.

There is one other food plant that may have been introduced by the natives, and that is the *ti pore* (*Cordyline terminalis*). It does not seem to have been known here in a wild state, but was cultivated in the far northern part of the North Island only, for the sake of the fecula or sago contained in its roots. It was very nearly extinct when recognized by Europeans (see *Trans. N.Z. Inst.*, vol. 33, p. 301). The *ti para*, another species, or variety, of *Cordyline*, was also grown for the same purpose by the natives, and I could never get any old native to admit that it grew wild.

The *ti para* is a puzzling form, and has apparently been neglected by botanists.

A tradition collected in the far north tells us that the natives still remembered the coconut of their former home, under the name of *ni*—the *niu* of many Polynesian dialects.

The illustration shows a *taro* plant seen at Koriniti, Whanganui River. The natives have almost ceased to cultivate the plant, and the *kumara* is now a very minor quantity in their fields. the native gourd is almost extinct, and the yam (*uhi*, *Wiascorea* sp.) was lost many years ago. The latter was a difficult plant to grow here, and was probably allowed to disappear

when the potato was introduced. In the far north the traveller sometimes sees the *taro* growing in streams near the site of former native hamlets or gardens. The Maori did not irrigate his *taro* crops, as was done in many Pacific lands.

The *taro* produces very fine leaves, and is an extremely handsome plant. Not only was the root eaten, but also the leaf-stalks or petiole, called *whawha taro*.

Candolle states that the *taro* grows wild in India, Ceylon, Sumatra, and other isles of Indonesia. One of its Malay names, *taloes*, is evidently connected with the *taro*, *talo*, *dalo*, and *kalo* of Polynesia and Melanesia. Once acquired by the old Polynesian voyagers, they would soon carry it far afield, for they ever carried their economic plants with them in their sea wanderings. The introduction of the *aute* (*Broussonetia papyrifera*) into New Zealand from Polynesia is an interesting case of this kind.

NOTE CONCERNING A SPINELESS WILD-IRISHMAN (DISCARIA TOUMATOU).

By L. COCKAYNE, Ph.D., F.L.S., F.R.S., F.N.Z.Inst.

THIS note is intended to serve the twofold purpose of putting on record the occurrence in the ordinary habitat of that well-known shrub, the wild-irishman (*Discaria toumatou*), of an almost spineless individual of that species, and of correcting an error concerning another supposed spineless form which, recently, I unwittingly made.

As is well known, *Discaria toumatou*, in its usual form, is a semi-divaricating shrub, 1 m. to 2 m. high, but varying greatly in stature, which is furnished abundantly with rather long, sharp spines, these being, morphologically, reduced shoots.* In 1905 I published an account of an experiment which showed that so long as a plant of the wild-irishman was cultivated in an atmosphere saturated with moisture it would not produce spines, but only leafy shoots similar to those of the seedling.† Eventually the leafless plant was transferred to the open ground, where it commenced to produce spines in a week or two, and very soon it became a typically spiny plant.

Towards the close of the year 1920 I had the pleasure of receiving from Professor J. Park specimens of a wild-irishman, growing near Queenstown (South Otago Botanical District), which he was inclined to consider as belonging to a species distinct from *Discaria toumatou*. He mentioned that he had found two bushes of this novel plant. I at once and unhesitatingly came to the conclusion that the plants in question were what I had long expected to find or hear of—semi-juvenile forms of *D. toumatou*. So sure, indeed, was I of the correctness of this assumption that I added a note to that effect in the appendix to my book on New Zealand plant-geography.‡ The note says: "The twigs are slender, drooping and not stiff, the spines are more or less soft and the flowers comparatively few. The plant might well be considered as a form growing under especial shade and moisture in the air, yet the two bushes are side by side with the usual intense xerophytic form of the species." Not long after writing this I had occasion to visit Queenstown, and at once went in quest of Park's plants, one of which was easily found. This shrub is of much denser habit than the usual form, and a careful examination led me to the conclusion that the whole plant was a "witches' broom" given off from near the base of the main stem. I have seen the plant several times since and am pretty certain that such is the state of affairs. This is confirmed by the fact that I have since found "witches' brooms" —but of much stiffer habit—on a good many *Discaria* bushes near the head of Lake Wakatipu.

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* See L. COCKAYNE, An Inquiry into the Seedling Forms of New Zealand Phanerogams and their Development. *Trans. N.Z. Inst.*, vol. 32, p. 93, 1900.

† *The New Phytologist*, vol. 4, pp. 79–85, 1905. In this paper the duration of the moist-air culture is given as "more than three years," but in point of fact it was seven years.

‡ *The Vegetation of New Zealand* (*Die Vegetation der Erde*, XIV), p. 332, 1921.

[*W. D. Reid, photo.*

Fig. 1.—The almost spineless plant of *Discaria toumatou* as growing in the Dart Valley, Lake Wakatipu.

[*W. D. Reid, photo.*

Fig. 2.—The ordinary spinous form of *Discaria toumatou* growing side by side with the spineless form in the Dart Valley.

A little later in the year, while staying at Kinloch (head of Lake Wakatipu), I inquired from Mr. Bryant and his family if any of them had ever seen a matagowrie (the local name for *D. toumatou*) without "prickles." The young son, Jack Bryant, at once answered in the affirmative, and conducted me to the *Discaria* scrub on the old river-bed of the River Dart, where, indeed, was a veritable wild-irishman, almost without spines, and growing side by side with its spiny relatives fully exposed to sun and wind!

The shrub in question is about 1·8 m. high. The twigs are drooping (see *loc. cit.*, fig. 1)—a rather interesting point in view of the drooping character of the shoots of the plant, referred to above, as cultivated in moist air (see *loc. cit.*, fig. 2)—some twigs are quite spineless, and others with a few spines, either very stunted or up to 18 mm. long. There appear to be two plants side by side, but both may come below the surface of the ground from the same main stem. Alongside are shrubs of the ordinary divaricating spinous form (see fig. 2). The shrub is quite without the dense habit of the witches'-broom form.

On returning to Queenstown I took cuttings of purely spineless shoots to the head gardener of the Domain, Mr. Hesketh, in order to see if he could strike them. Although the time of year was not the best, and no one has had experience in propagating the wild-irishman from cuttings, Mr. Hesketh succeeded in raising two rooted plants, one of which is now in my garden and the other in the Queenstown Domain.

Although I have previously seen *D. toumatou* less spiny than usual, I have never before seen a form so free from spines, or so different to the usual habit of the shrub (see *loc. cit.*, fig. 2). Professor A. Wall, in his recent articles entitled "The Botany of Christchurch," which have appeared in the *Lyttelton Times*, mentions (1st May, 1922) that Mr. James Mitchell quite recently discovered a spineless variety of wild-irishman on the dunes near New Brighton, but no particulars are given. Possibly, if one looks for such, these spineless plants may have quite a wide range.

The interesting point concerning the production, on the one hand, of a spineless form by moist-air culture, and, on the other hand, the occurrence of such forms in nature, and of a semi-juvenile form as the result of fungoid attack, is a difficult genetic and physiological problem, for which details essential for its solution are lacking. I hope to raise seedlings from the Kinloch plant and to experiment with small plants raised from the spineless plant now in my garden; such investigation may shed a little light on a difficult question.

NOTES ON THE LIFE-HISTORY OF MONOPIS ETHELELLA (NEWM.) (TINEINA, LEPIDOPTERA).

By J. G. MYERS, F.E.S., Biology Laboratory, Department of Agriculture.

SOME soiled wool from which several species of sheep-maggots had been reared was found, when in a rather drier condition, to be swarming with these small but handsome moths. Further examination brought to light

all the stages except the eggs, which were not discovered. The larva is a typical internal feeder in shape and colour, being pale-yellowish-white with a shining brown head. With the help of its short legs and five pairs (including the anal pair) of well-developed hooklet-encircled prolegs it burrows in the mass of wool, matted thickly together with excrement and grease. Rough tunnels littered with frass and rubbish are made in this material. The average length of the larva is 12 millimetres.

Before pupation the larva works its way through the mass, leaving the congested portions on which it has been feeding, and reaches the looser wool near the edge. This is obviously to facilitate the emergence of the moth—a process for which even further preparations are to be made. The cocoon may be as long as 15 millimetres, but is usually shorter. It is spun in such a position that, while its posterior end is held firmly by the entangled fibres incorporated in its structure, the anterior lies almost clear among the looser fibres of the periphery of the mass. It is cylindrical with rounded ends, the anterior end slightly flatter, and perforated by a transverse slit extending with closed lips across the extremity, and protected by outwardly directed fibres, making egress easy but ingress practically impossible. Inside, the cocoon is lined with pure-white silk of the smoothest texture. Its wall is made up of interlacing wool-fibres fastened together with silk; but in many cases the wool-fibres seem to be but little more than fastened to the outside of the strong silk lining.

The pupa, which with the larval exuviae at its abdominal end occupies but a portion of the cavity of the cocoon, is approximately 9 millimetres in length and in shape somewhat elongate. The posterior edge of the dorsum of every one of the last six segments bears a backwardly directed collar with its edge cut into minute regular teeth like those of a comb. The apparent ultimate segment bears at its dorsal extremity a peculiar prong, directed upwards, and produced into two sharp tines like those of a pitchfork. These structures are evidently used to push the pupa partly out of the cocoon. The wing-cases are not fastened to the body for the greater part of their length.

In preparation for the emergence of the moth the pupa pushes itself out till about the second of the ctenidial ridges is clear of the cocoon, the anterior portion of the pupa, along which the split for the last ecdysis occurs, being thus projected clear of all wool. Emergence is rapid, the tiny wing-pads developing with considerable speed.

The moths of the genus *Monopis* are said by Meyrick to find their larval food in refuse. Since rearing this particular species from foul wool as described above I have found the adults (10th June) emerging in considerable numbers from the woolly debris of a dead sheep long since in the bone-and-wool stage of dissolution, lying at the base of the cliffs at Breaker Bay, Wellington. The moths shelter among the caked masses of wool during the day.

This moth has been recorded throughout New Zealand from Auckland to Dunedin, and from sea-level to an altitude of 4,000 ft. It is common also in Australia. The *Index Faunae Novae-Zealandiae* (Hutton, 1904), under the misspelling *Monopsis*, records it as an introduction from Europe, which is surely an error.

THE COMMERCIAL ASPECT OF WATER-POWER DEVELOPMENTS IN NEW ZEALAND.*

By F. T. M. KISSEL, B.Sc., A.M.I.C.E., A.M.I.E.E., Electrical Engineer, Public Works Department, Wellington.

SCOPE OF MR. MOORE'S PAPER.

THE paper generally criticizes the Department's policy of adopting three main large sources of supply for the North Island as not being conducive to such economical supply as would the development of a larger number of smaller sources in localities more adjacent to the immediate loads to be obtained. He also claims that the Department's estimate of the probable requirements of the country—viz., $\frac{1}{5}$ horse-power per inhabitant on the 1916 census—is too optimistic for the present state of development in New Zealand. To illustrate his argument he quotes statistics and records from a large number of Swedish water-power installations. He adopts the costs of average Swedish conditions, and, after modifying them to suit New Zealand costs, evolves a scheme of power-supply from 125 stations of varying sizes to take the place of the supply proposed under the Government scheme to be given from three different stations, at Arapuni, Waikaremoana, and Mangahao. Similarly he takes the three Government stations and adjusts the estimates of capital expenditure given in Mr. Parry's report of 1918 to suit present-day costs, and arrives at a selling-price for power on what is represented to be the same basis as from his number of smaller stations. As he claims that the Government's estimate of the power required is too optimistic, he also analyses the costs of production for similar schemes with a total generating-capacity of 80,000 instead of the 160,000 horse-power in the main scheme. As a result he claims that at the 160,000 h.p. stage power delivered will cost £4·74 per horse-power-year at the main substation under the Government scheme, and £5·18 under his alternative scheme of many generating-stations; but that at the 80,000 h.p. stage power would cost £5·98 per horse-power-year on the Government scheme, and £5·14 per horse-power-year on the alternative scheme proposed by him.

Mr. Moore's paper shows signs of careful preparation, and his arguments are well set out. It, however, fails, I consider, in two or three fundamental general principles, and his deductions are not borne out by actual results that have so far been obtained in this country.

IMPORTANCE OF SUBJECT.

New Zealand is particularly richly endowed with good sources of water-power, and the question of their development is one of the greatest importance, both to enable the Dominion to develop its existing industries in the most economical way and to compete successfully in the world's markets, and also to enable it to establish and develop new ones that will help to make us more and more independent of the older countries in the supply of our own needs. The fact that there is an abundance of water-

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* Being a reply to the paper by W. Lancelot Moore, A.M.I.C.E., in *N.Z. Jour. Sci. & Tech.*, vol. 5, No. 2.

power does not necessarily make the design of a scheme to meet the needs of the country easier, because it makes possible many alternatives which must all be considered before a definite policy can be laid down.

The scheme of a supply from a large number of different sources of power of varying size, as outlined by Mr. Moore, is not new, and was one of the schemes of development considered by Mr. Parry, then Chief Electrical Engineer, when drawing up the scheme which had been adopted for the supply for the North Island of New Zealand.

General Objections to a Supply from Small Stations.

There are quite a number of objections that can be raised on general grounds to a supply from a number of stations, as opposed to a supply from a limited number of large stations. Amongst these might be mentioned the following :—

Diversity of Load.

The total plant required to supply the same load can be considerably less if concentrated in a few large stations, interconnected by a transmission-system, than if it is spread over a number of individual stations. This is mainly on account of the diversity in the load that will occur between different districts, resulting in the peak load in one place occurring at a different time from the peak load in another. It is evident that if the load in each particular district is to be carried by a plant of its own, that plant must have a capacity, with some spare, to meet any demand that may be made upon it ; whereas the plant in a large central station is available to meet the peak loads, or any special emergency load that may arise in any district connected to its transmission-system.

The capital cost on the undertaking becomes less on account of having to provide a smaller total plant capacity ; the capital cost is further reduced because the cost of plant is very considerably less when large units are installed as against smaller ones, and the efficiency of the large ones is greater than that of the small ones.

Considering this in particular relation to the scheme submitted by Mr. Moore, we find that his comparison is based on requiring a plant capacity of 150,000 h.p. in each case to supply the needs of the country. This is a very serious error, because, as explained above, it will require a much greater plant capacity to supply the same amount of power for many small stations than from the three interconnected large ones. The extra plant capacity will, of course, mean extra capital, and as capital charges are by far the biggest item in the total annual costs, the annual costs must be considerably increased. By way of comparison I might state that the total supply from our Addington substation is sent out by twelve distributing-feeders. We might consider each of these feeders as a station supplying a particular district such as would be supplied by one of the smaller of Mr. Moore's stations. We find that, owing to the diversity in the load in the areas supplied by these feeders, the sum of the peak loads on the individual feeders is, on an average, about 1·3 times the peak load on the substation ; or, if the supply were made from twelve independent stations instead of from one, that the separate stations would have to have at least 1·3 times as much plant as the single one. With the diversity of load over the whole of the North Island available under the Government scheme with several main substations to each generating-station, it is likely that this figure would be considerably increased.

It is true that a certain amount of diversity between districts might be obtained under Mr. Moore's schemes by interconnecting adjacent power-stations, but, on account of the general average low voltages that are an important adjunct to his system, it would be possible to transmit only limited amounts of power and only short distances. Moreover, no provision for such is made in the scheme he has outlined, and if such is to be made, then the capital cost must again go up and the annual charges be still further increased.

Creation of Industries.

One of the most important advantages of a large central supply system as opposed to a number of stations supplying localized requirements is that it will encourage industries, not only because of the lower rate at which it will be able to supply, but because the plant capacity at the main stations can be increased very considerably at comparatively little added capital cost and practically no added operating-cost. On the other hand, local stations would be designed to supply the particular needs of their immediate neighbourhood, and in all probability, if a new industry wished to establish itself there, it would be forced to develop power of its own. The fact that it would have to provide the extra capital necessary to provide a power-generating plant would probably make the establishment of the industry impossible. This is particularly applicable to such things as mining, sawmilling, and paper-pulping, which have a rather limited life in any particular district. An individual power-station installed for mining purposes in one particular locality might be quite useless when that mine worked out and others were established in some other locality, whereas, if that mine were taking its power from a central supply system, the closing of a mine in one district and the opening of another in another district would make very little difference to the system generally. The fact that power was available generally throughout a district would thus make numbers of mining propositions to be worked which could not possibly be profitable if they were called upon to provide special capital for power-generation purposes for limited periods of operation.

Modern Developments make Comparison with Previous Conditions useless.

The method of development which has occurred in Sweden, and which Mr. Moore proposes should be adopted in New Zealand, is what has occurred in practically all the older countries where electric power has been developed. The reason is not, however, wholly, as inferred by him, to allow the undertaking to grow with the demand and population, but because when the earlier Swedish schemes were established such a scheme as now adopted for the New Zealand Government supply in the North Island was not possible. High-tension transmission had not then developed, and it was thus impossible to transmit large blocks of power over long distances. Nor had the large-size water-wheels and generators then been built that make the modern central station such an economical proposition. The increasing reliability in insulator-construction makes possible now what was quite impracticable when the earlier Swedish stations were installed. I would have no hesitation in saying that if those countries which have gradually adopted a large number of small stations scattered over the country were now called upon to redesign the whole of their electric-supply undertakings they would adopt a system of supply from a lesser number of large units, if such were available, rather than go back

to the system of supply from a number of small ones. This matter has been investigated at much length by special committees set up during the war period both in England and America, and their findings have always been in the direction of advising large interconnected stations as against numerous small plants.

The Advisory Council set up by the Ministry of Munitions in England, asked to report on the question as to whether electric power should be generated on a national system, definitely advised such a course, and (*inter alia*) stated that "the present system under which a supply of electricity is provided in a large number of small areas by separate authorities is incompatible with anything that can now be accepted as a technically sound system."

Local and Political Influences.

Mr. Moore claims that by pushing local schemes in the way advocated in his report the people directly concerned with the supply of power would become actively interested in the development, and so remove the political influence which he claims as a big handicap to Government undertakings. I fancy that the tendency would be rather the other way, and that the adoption of a scheme for a number of small-power stations would result in a continual political agitation for the development of local water-powers proposed and agitated for by persons with purely local knowledge or with some personal reward in view, and would almost inevitably result in the adoption of a number of schemes which could only be financial failures. If these smaller schemes were developed by private enterprise, then the chances of the large Government scheme coming along and replacing them with a more efficient service at a later date would be reduced, on account of the influence that would be brought to bear to safeguard the interests of the persons directly concerned in the existing undertakings. This has been one of the most serious influences in restricting and delaying the complete carrying-out of the scheme of the Advisory Council of the Ministry of Munitions mentioned above.

Town Loads at Expense of Country.

Independent generating plants would in the ordinary course of events be always established close to the towns and densely settled localities, and, as there would be no need of transmission-lines through the more sparsely settled districts, such districts would have to go without all benefits of electric power, because the high capital cost of headworks would probably make any scheme of development for them alone prohibitive in cost; thus, though the country man might be just as much in need of electric power, and could appreciate its advantages just as much, as the man in the town, he would be deprived of any chance of getting it.

Time for Construction.

A central station would take less time to construct than a number of small stations of total equivalent capacity, and so would be able the sooner to get into operation and dividend-paying condition. Another quite important factor in a country in the state of development we have now reached is that fewer men, particularly of the skilled class, would be required to install one large station than would be required to install a number of small ones.

These facts all tend to reduce the total capital expenditure on the central-station scheme; and when we remember that capital charges on the investment represent 70 to 80 per cent. of the total charges for power delivered on to the distribution-system, and when we consider that it costs very little more to operate a station of 50,000 h.p. than it does to operate one of 5,000 h.p., it is evident that the development of large stations is from all points of view more likely to give economical results than is development of a large number of smaller ones.

SWEDISH CONDITIONS NOT APPLICABLE.

Considering more particularly the arguments as set out by Mr. Moore, it is quite impossible to take average Swedish conditions and apply then generally to New Zealand conditions. His scheme involves the construction of 125 power-stations; but it is certain that it would be impossible to find enough stations of the nature required in his scheme to fit into actual New Zealand conditions. The power-supply to the North Island is not one which can be decided on averages, but every individual case must be decided on its merits; and I think in practice it would be found that, if any scheme of multiple supply were found necessary, Mr. Moore's figures would have to be adjusted to such an extent that they would be useless for the purposes of comparison with the definite proposals of the Department. The only reasons given by Mr. Moore for adopting Sweden as the country whose water-power proposals should be compared with New Zealand are that its area is one and three-quarter times and its population five times that of New Zealand. Other factors which have probably a greater influence on the form this development would take are the period at which this development is to begin, the physical and geological features of the country, the distribution of population, the rainfall and climate, the industries, and the probable diversity of loads. From Mr. Moore's Table 2 it would appear that 95 per cent. of the hydro-electric stations in Sweden are operated by private companies, and that the average size of those stations is 960 h.p. each, while the remaining 5 per cent. operated by the State or by municipalities average 7,850 h.p. each, whilst of these the three that are State-controlled average 71,000 h.p. each. It is only natural that the State should be the body which would provide a service which would be considered best suited to the needs of the community generally, and that the private companies would provide services which were best calculated to serve their own immediate purposes. The size of station provided by these three authorities is about an indication of the degree to which each of them might be expected to serve the interests of the country as a whole, and it is interesting to note that in Sweden, as is proposed in New Zealand, the State is developing the large sources as being the ones best suited to the needs of the country.

COMPARISON WITH CANADIAN CONDITIONS.

The generation and supply of electricity as a special business is probably more largely developed in Canada than in Sweden, and to ascertain what has been the practice in that country particulars of Canadian water-power stations have been analysed in the same way as Mr. Moore has analysed the Swedish ones. As is natural in all countries, and as has been the case in New Zealand, numbers of small stations have been developed in the earlier ages of power-supply and in isolated localities, but the general tendency now appears to be to go in for bulk supply from large stations.

The Canadian water-power stations grouped similarly to Mr. Moore's Table 3 would be,—

Size of Group (Horse-power).	Stations.		Total Output.	
	Number.	Percentage.	Horse-power.	Percentage.
0– 200	89	35	8,857	0·53
200– 500	52	20	17,154	1·01
500– 1,000	22	9	16,845	1·00
1,000– 5,000	54	21	149,023	8·90
5,000–10,000	9	4	54,400	3·23
10,000–20,000	11	4	148,150	8·83
20,000–50,000	12	5	401,800	23·95
50,000 and over	6	2	877,300	52·56

Or, if the analysis were continued, and a grouping arranged to suit the 160,000 h.p. proposed for the North Island, but based on past Canadian practice, as Mr. Moore's Table 8 is based on past Swedish practice, we would get the following scheme of stations for the North Island supply for Canadian and Swedish conditions respectively :—

Size of Group (Horse-power).	Stations.				Total Output.			
	Canadian.		Swedish.		Canadian.		Swedish.	
	Number.	Percentage.	Number.	Percentage.	Horse-power.	Percentage.	Horse-power.	Percentage.
0– 200	7	30·5	35	40·8	850	0·54	6,400	3·95
200– 500	5	21·7	32	25·6	1,620	1·03	11,200	6·95
500– 1,000	2	8·9	19	15·2	1,600	1·01	14,300	8·95
1,000– 5,000	5	21·6	18	14·4	14,100	8·90	51,000	31·75
5,000–10,000	1	4·3	3	2·4	5,160	3·26	22,500	14·06
10,000–20,000	1	4·3	1	0·8	14,000	8·85	15,000	9·35
20,000–50,000	1	4·3	1	0·8	36,700	23·20	40,000	25·00
50,000 and over	1	4·3	..	..	84,000	53·11	..	..
	23	100·0	125	100·0	158,030	99·90	160,400	100·00

This indicates that the percentage of power developed in the large stations is very much greater in Canada than in Sweden, and that the Government's proposals for a supply to the North Island are more in line with what has taken place in Canada. We might quite well consider the 84,000 h.p. scheme in the table above as representing Arapuni, the 36,700 h.p. one Waikaremoana, and the 14,000 h.p. one Mangahao, with the twenty smaller ones of varying sizes as representing the existing water-power stations at New Plymouth, Wairoa Falls, Tauranga, Raetihi, &c. If Mr. Moore's method of analysis were still further followed, and his typical average costs per horse-power applied to these Canadian stations as he has done with the Swedish ones, we should arrive at a total capital cost considerably lower than the one on which he has based his argument, and so prove that a scheme designed to follow Canadian conditions, or containing a larger proportion of large stations, would give more economical results than does his scheme.

PROBABLE LOAD.

Mr. Moore is very emphatic that the Department is too optimistic in its estimate of the probable load that can be obtained for its supply system; and, as his own figures prove, and he admits, that the Government scheme will be the more economical when the 160,000 h.p. stage is reached, he has developed and compared a development of only half that size. The Department's scheme is based on population figures from the 1916 Year-book to give 0·2 h.p. per inhabitant to the population shown therein, after making adequate allowances for spare plant; and the report of 1918 stated that it would take at least ten years from commencement to be developed to the 160,000 h.p. stage. At the end of this period, at the natural rate of increase of population, the allowance per inhabitant would be about 1 h.p. for every 6·7.

The following figures have already been obtained from New Zealand water-powers in the supply areas allotted them, though these areas are not wholly reticulated, and in most cases the supply has been seriously restricted owing to shortage of plant: Hawera, 1 in 9·7; Inglewood, 1 in 8·7; Mangaweka, 1 in 8; New Plymouth, 1 in 9·7; Coleridge, 1 in 11; Waipori, 1 in 10; Taihape, 1 in 11; Ohakune, 1 in 6·4.

To show the confidence local authorities have in the growth of load, New Plymouth have recently embarked on a scheme to increase their capacity from 1,550 h.p. to 6,000 h.p., Tauranga have increased their plant from 210 h.p. to 1,000 h.p., and Auckland City Council have ordered additional plant (steam) to bring their capacity up to 19,500 kw., or 1 h.p. to every three of present population.

The *per capita* consumption and probable growth of load, &c., has been very carefully investigated by special committees set up for the purpose in the western States of America.* For these States, west of Rocky Mountains, the ratio in 1920 between installed plant and population was 1 in 3·4, but the investigations of this committee showed that the amount of power used was increasing at a considerably faster rate than was the population. The increase in population for the ten years 1910–20 was 30 per cent., whilst the installed plant in the generating-stations had increased 133 per cent. It was anticipated that by 1930 the installed plant would have increased to 1 h.p. for every 1·54 of the present-day population. In Canada in 1920 the proportion was 1 in 3·6, and in Sweden the 1917 ratio was 1 in 3·85. All of which figures show a very much greater use of power than is provided under the Government's scheme of 1 in 5 on the present population made available in ten years' time.

Mr. Moore will probably know that an English company, with important water-power connections in Sweden, has recently recommended and made offers to construct for certain New Zealand local authorities a water-power to develop a load equal to 1 in 7 of the population to be served. The 6,000 kw. development on the Waikato recently acquired by the Government serves to illustrate that the load will develop if that development is in the hands of some organization whose special function it is to sell power. This scheme has been installed and was being operated by a private company for six years, with full powers to distribute and sell power over a large area, yet in that time the load has not grown beyond 3,000 kw.—half the capacity of the plant; but though this plant has only been taken over for less than two years, already the load has grown to almost the limit of the station, and additions are necessary and are being made.

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* See *Journal of Electricity and Western Industry*, vol. 46, June, 1921.

The 80,000 h.p. Stage.

Mr. Moore's own figures prove, and he admits, that the Department's proposals are the more economical at the 160,000 h.p. stage, but he attempts to prove that at the smaller development his group system is the better. The figures used to prove this, however, need considerable adjustment before his comparison can be considered equitable, even if it could be admitted that it is possible to take average figures from some other country and apply them to developments which may or may not exist, and then compare them with the Department's definitely ascertained information.

His figures of capital cost, the annual charges on which go to make up 80 per cent. of the total annual cost of the power, have got to be adjusted and increased, on the following grounds :—

(*a.*) On account of the greater amount of plant that must be provided in his scheme to cater for the same load, as discussed above. This would amount at least to an addition of 30 per cent., whereas he has considered them equal in each case. This addition alone would increase the annual cost by about 22 per cent., and make it above that given for the Government scheme even at the 80,000 h.p. stage.

(*b.*) On account of the higher interest and depreciation charges that should have been carried by his scheme. He states that under his proposal these charges will have paid for the plant in twenty years, and so allow the bigger scheme to be then adopted. There is no proposal and no need for the Department's scheme to have completely paid for itself in this time, and capital charges on it at 1 per cent. less than the group scheme would be quite reasonable. This alone would reduce the cost of the Government supply by at least 10 per cent., bringing it still further below the alternative group scheme even at this stage of development, on account of no provision having been made in the group scheme, as has been done in the Government one, for the cost of storage-basins, land and compensation, water-rights, &c.

ARAPUNI PROPOSALS.

There are one or two specific criticisms of the Government schemes in the paper which cannot be allowed to pass without comment. The statement is made that considerable savings would be made by building four dams each 40 ft. high in place of the one dam 160 ft. high at Arapuni, on account of the reduced amount of concrete that would thereby be required. There may be a saving of concrete, as shown in the actual superstructure of the dam, but a very large proportion of the cost of any dam lies in the preparation of the foundations, in the diversion or other manipulation of the water during construction, and in provision for lowering the water from its new elevation down to the original level of its course. At Arapuni these costs amount to 30 per cent. of the total cost of the dam, and, as the same amount of water has to be dealt with in each case, would be much the same for each of any alternatives that might be devised. The cost of all other sections of the hydraulic works would also be considerably increased, as gates, pipes, turbines, &c., would each have to deal with four times the amount of water to give the same amount of power, as with the greater head at Arapuni. Alternatives would also be more expensive on account of slower speeds necessary for machines of equal size driven by water-wheels operating at a lower head.

The main immediate load on Arapuni, or any other source of power on the Waikato, must be in Auckland, and as Auckland City Council already have on order an efficient steam plant totalling 26,000 h.p. there is no need to consider any scheme for them of less than this amount. When the Auckland load grows beyond this amount, as it is anticipated it will do in six or seven years' time, Arapuni can supply it at a rate which will enable the City or Power Board to pay capital charges on and retain its steam plant for purely stand-by purposes. This is apart from load that can be secured in other districts. The load necessary to make Arapuni a payable concern is thus assured within a very short period after the time in which it can be put into operation, and additional loads to 160,000 h.p. can be obtained at additional costs of very little more than the cost of the actual generating plant.

WAIKAREMOANA PROPOSAL.

Mr. Moore's paper claims, because the Department has altered the design of the Waikaremoana works to provide for two power-stations where only one was provided in the original scheme, that it is better to adopt a scheme of several smaller stations in place of the three large ones. The alteration of Waikaremoana designs is not on account of any such consideration, nor can the amended design in any way be considered as being part of such a scheme as he proposes, as the subdivision of the large fall available into two sections has been decided upon purely on economic grounds, rendered possible by the high state of efficiency to which the automatic remote control of electrical machinery has reached, and necessary on account of the high prices of steel-pipe lines at the present time. The second station will contain water-wheels and generators only, the whole of the switch-gear for which and the operation of which will be controlled from the one main station. Indeed, as this scheme develops a third generating-station will be built, and this in turn controlled from the one main station. These stations will be all comparatively close together, and controlled by one staff, and in no way depart from the general scheme laid down in the Government's 1918 report. The fact that the available head has been cut up into sections is only an indication that the Department's engineers are alive to modern improvements and the economic conditions existing at the time, and are not wedded and tied down to any preconceived ideas.

CONCLUSION.

The paper under discussion admits that the Government's scheme in general and at the 160,000 h.p. stage is an ideal one, and only claims that at some lesser stage the group system of many power-stations is a better one. The experience of other countries where electric power has been available, and particularly if it is made available in advance of the actual visible requirements, all show that more than the amount of power proposed to be provided by the Department is actually being used, and that the amount of power used per inhabitant is also rapidly increasing. There is little doubt, therefore, if the amount of power proposed were made available the power could be profitably sold and used within a short period.

Even with the more modest proposals at 80,000 h.p.—and it was never proposed or intended that absolutely the whole of the 160,000 h.p. should

be installed at the very commencement — an equitable consideration of the matter shows that the Government's proposal is the better one.

The only objection that can really be raised against the scheme is that one or two localities may consider themselves penalized by having to wait until the proposals can be carried out. Any hardship on this account can, however, only be of local extent, and will be more than counterbalanced by the benefits that will accrue when they are connected into the system. There may always be a few isolated localities remote from any of the Government's main substations, and which may possess particularly favourable local schemes. There should be no objection to these being developed for purely local purposes, as their installation would not interfere with the Government scheme in any way.

There is a grave possibility, however, if this scheme of individual stations throughout the country, as proposed by Mr. Moore, were embarked upon, apart from specific cases above, that the installation of the Government proposals would be very seriously delayed and the whole country penalized accordingly.

These schemes could not, as suggested by Mr. Moore, be all installed so that the sums set aside for sinking funds would have paid them off by the time the Government scheme was ready to take up the load, and in consequence the cost of power generally would have to be increased to carry capital charges for some time on both the local and the Government schemes. If, indeed, the sinking funds could be so adjusted there is no doubt that it would be impossible to put all these local schemes out of action when the main supply was available, on account of local prejudices and vested interests concerned in their management and operation; and, again, the cost of power to the remainder of the country would be increased on account of the reduced load over which the capital costs of the main supply could be distributed.

The Government scheme has been designed to meet not only the prospective needs of ten years hence, with the possibility of extension to meet those of the next thirty years, but the three individual stations comprising the system are designed to meet the requirements of the main centres of load as soon as the local plants now in operation or in course of construction have reached their economic limit. No alternative to Mangahao of sufficient capacity to supply the needs of Wellington alone has been proposed for the Wellington and Manawatu districts. Arapuni can supply Auckland with power at exceedingly attractive rates once the load has grown beyond the limit of the steam plants they have recently purchased, whilst for the east-coast districts no alternative can supply the needs of Gisborne and Napier comparably with Waikaremoana.

It is to be regretted that present high interest charges and high cost of construction render it inadvisable to proceed with the scheme as a whole at the present time, but these same agencies act adversely in exactly the same way against the smaller schemes. It is certainly better to wait for a limited time wherever possible, rather than embark on an alternative which can only delay the main proposal and put up the cost of power for many years afterwards. It is better, rather than follow the practice which has already become obsolete in the older countries of the world, that we should benefit by their experience, and as soon as conditions are favourably embark on a scheme of electric supply which, whilst capable of economically supplying the immediately prospective demand, is capable of simple extension for the needs of the future, and one which can be compared favourably with anything existing elsewhere in the world to-day.

WHITE ISLAND.

By Colonel G. ARNOLD WARD, C.B.E.

WHITE ISLAND, known to the Maoris as Whakari, is situated in the eastern portion of the Bay of Plenty, its nearest point on the mainland being Whakatane, though for some fifty miles the coast-line north-east from that town almost seems to have been drawn with a pair of compasses with the volcano, thirty-two miles distant, as the central point. Tauranga, situated on the harbour of the same name, lies fifty-seven miles roughly west-south-west from the island. The prosaic Admiralty chart aptly describes it as "constantly ejecting steam"; but the old-time Maoris would seem, by their poetic traditions, to have regarded it as of a more fiery nature, for they relate how the Goddess of Fire, being summoned hastily from far Hawaiki to save a chief (who happened to be her nephew) from perishing with cold on Tongariro Mountain, came down from the heavens for a rest on Whakari, after her long flight, and set the island on fire. Thereafter she very literally blazed her trail to Tongariro by setting fire to quite a lot of other places as she went along, of which we have ample evidence to this day if we follow her footsteps by Motuhora (Whale Island), Putauaki (Mount Edgcumbe), Rotomahana, Ohaki, Wairakei, and so on to Tongariro and Ngauruhoe.

DESCRIPTION OF THE ISLAND.

Viewed from the sea at a time when the volcanic forces are unusually quiet and no steam can be seen rising above the crater-walls, the island does not present any striking features. In shape it is something less than two miles long, east and west, and a little over a mile wide from north to south, the chart showing the highest point as 863 ft., at about what appears to be the centre of the island. Further study of the chart, however, reveals it as a volcanic mountain of quite considerable proportions, whose base on the sea-bottom presents some characteristics well worthy of notice. Standing approximately about the hundred-fathom line in the Bay of Plenty, the island rises from a ridge running about north-west and south-east, and culminating to the north-west with Volkner Rocks, three miles distant, these being needles, the highest of which rises to 150 ft. above the sea. The ridge extends 342 ft. north-west of the island and a trifle less on the south-east side. West of the island there is a depth of 101 fathoms, while east, and barely a mile from the island, 181 fathoms are shown, giving this face, viewed as a mountain rising from the sea-floor, a total height of 1,991 ft.

Closer inspection of the island reveals a striking resemblance to a hollow back tooth, the crown being hollowed out and the outer walls breached in two places. Before landing, there is one other feature of the exterior which gives it a sinister aspect—namely, the almost complete absence of vegetation. This might be attributed to the emission of poisonous gases from the crater, but the presence in spring-time of a numerous gannet colony nesting on the south-western point of South-east (or Crater) Bay seems to show that the general barren appearance of the

outer slopes must be due either to lack of suitable plant-food or to too frequent sprinkling with volcanic debris of the finer sort. Prior to 1914 landing was usually effected on the boulder beach of South-east Bay, and the eruption of September of that year greatly improved the landing-facilities in both bays by filling in and overlaying the boulders with finer material, making landing much easier than formerly.

Prior to 1912, on moving up the beach, one continued up a gentle slope to a height of about 30 ft. to 35 ft. above high water, and then, arriving within the crater, found a fairly level floor of general volcanic debris, surrounded by towering cliffs, 100 ft. to 150 ft. high, immediately to right

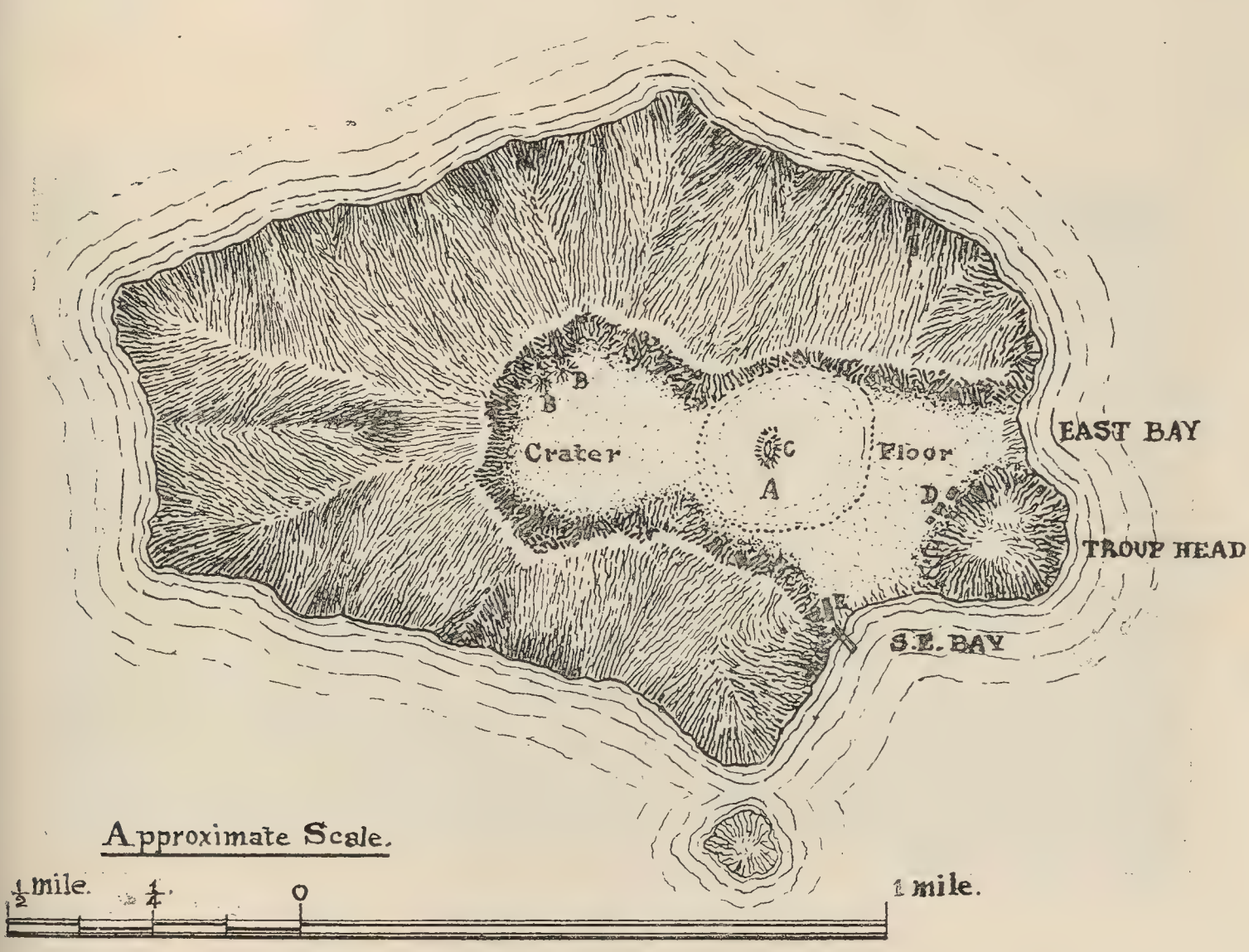


FIG. 1.—Sketch-map of White Island.

A, site of hot lake (strongly impregnated with hydrochloric acid) as it appeared in 1897; B, B, the principal old fumaroles; C, the big new fumarole, opened during eruption of September, 1914; D, site of workmen's huts, erected about 1912, destroyed by eruption, September, 1914; E, boiler and storage sheds, wharf, &c., also totally destroyed.

and left, but steadily rising in height on both north and south sides of the crater, and culminating around the western end with altitudes varying between 700 ft. and 800 ft. The impression produced on the occasion of my first visit, in the "nineties" of last century, and confirmed by two subsequent visits in 1914 and 1917, was that at some not very far distant period there had been two craters, divided by a comparatively thin wall, of which only traces remained in the form of projecting ridges from opposite points on north and south walls, sloping down towards the middle of the floor. Photographs taken at various periods since the "eighties" of last century seem to fully support this view, and also the further conclusion that the remains even of this former partition are being steadily

removed. The photograph looking along crater-floor from top of beach shows particularly well the destruction of the last remains of the base of the partition.

A great feature of the crater until 1912 was a lake of dilute hydrochloric acid—approximately 10 per cent. acid—nearly boiling, the steam from which had a painfully asphyxiating effect, particularly on any one with unusually sensitive bronchial tubes. This lake apparently varied considerably in extent from time to time. In the "eighties" it was impossible to reach the western end of the crater except by dragging a boat up from the sea and paddling across as rapidly as possible, a somewhat risky matter owing to the great heat and choking fumes. In the "nineties," when I first visited the island, the lake was much smaller, and a passage some 50 yards wide was available on the southern side between the water and the base of the crater-wall, making it thus much easier to reach the west

[*Colonel G. A. Ward, photo.*

FIG. 2.—Lake-bed and north-east part of crater.

end, where the two most active fumaroles were situated, about the base of the highest part of the cliffs. The accompanying photograph, taken in 1901, shows that the lake had then again taken possession of the entire width of the floor about the centre of the crater; but I gather from the friend who took this photograph that it was just possible to scramble past along the base of the south wall, and thus reach the great steam-holes. Ultimately, when a company was formed to work the sulphur deposits ten or twelve years ago, it was decided, for some reason unknown to the writer, to drain the lake, and this was effected, about 1912, by cutting a drain out to the sea. The lake, being only about 18 ft. deep, was thus eliminated.

Sulphur, generally in very pure form, is to be found everywhere, and small openings in cliffs and floor, emitting steam, sulphur-bearing vapour, and evil-smelling gases, were numerous, particularly in the western portion. The eastern part, about the base of the detached cliff-mass known as Troup Head, and between it and the lake, was practically quiet, and the material, as tested for many feet in depth, consisted largely of

sulphur and kindred valuable products of volcanic action, such as to tempt men to hazard their lives to get it out for export.

HISTORY OF THE ISLAND.

Of the history of the island from the scientific point of view, in the far-back ages, I am not qualified to speak, and can only tell of the very recent past. Captain Cook does not appear to have given heed to the island, but the Maoris, besides the tradition mentioned earlier herein, had other tales more or less marvellous, one of which dealt with a marooned chief, who escaped therefrom with the help of a pet whale—not, however, like Jonah, as a saloon passenger, but in the more exciting guise of a deck hand, the whale fortunately not submerging till it had landed the chief at his home port. Later the island was purchased by Messrs. Wilson and Troup, the former of whom, in the "eighties," formed a company to work the sulphur and manufacture acid at works erected for the purpose at Tauranga. A small party of men stayed on the island, and cutters brought the crude material to Tauranga. During these men's temporary residence on the island, I gather, they had occasionally some exciting experiences in the way of tremors, and the emission of dust and pebbles occasionally by the fumaroles, in sufficient quantity to cause them to regard it as prudent to embark in their whaleboat and lie off till things settled down. The company's venture proved unsatisfactory, and nothing further was done till some ten or twelve years ago, when another company was formed with similar intent; but on this occasion refining machinery was set up on the island, and the pure sulphur alone shipped away. As before, the huts and workings were situated at the eastern end of the crater (see sketch-map), and all went well till a date approximately fixed as the 10th September, 1914, when a disaster occurred, the exact nature of which can never be known, whereby every man on the island perished, and the huts, buildings, boats, wharf, machinery, tramways, &c., were smashed to fragments and swept into the sea by a stream of boiling mud.

Ten human lives were thus lost, nor was any vestige of the bodies of the men ever found. Of three cats belonging to the party, one was found alive by an exploring-party some three weeks later, and apparently only suffering from prolonged shortage of food. A strong easterly gale, just a fortnight after the supposed date of the disaster, brought ashore on the ocean beach between Maketu and Mount Maunganui (Tauranga) the wreckage from the island. Wharf-piles, tram-sleepers, house-timber, furniture, and scraps of all the three boats they had had at the island were washed ashore in great quantities, mostly smashed into fragments not more than 2 ft. or 3 ft. in length, the tram-sleepers and wharf-piles being about the only things that escaped practically unbroken.

APPEARANCE OF THE CRATER AFTER THE 1914 OUTBREAK.

On the 10th October, 1914, I had the privilege of visiting the island with the manager of the Sulphur Company. We found the old boulder beach covered with fine volcanic debris, and on reaching the top of the beach were confronted with an even surface of hardening grey mud, sloping gently upward for about 150 yards. The mud was opening with cracks as it dried out, and here and there were two or three small concentric rings sometimes with a little blob in the centre, indicating that the mud had boiled after it fell and had become practically stationary.

The work of previous exploring-parties, who had trenched the mud about the site of the former huts, showed us that the deposit was there from 2 ft. to 3 ft. deep. Farther up, the floor of the crater was studded with great mounds of debris, standing up like islands in the former sea of mud. Some of these were as much as 15 ft. to 20 ft. high, and we could not arrive at any very satisfactory theory to account for their presence so generally spread over the crater-floor. It was evident that there had been immense slips or cliff-falls about the western portion of the crater, and this appeared to cover a good deal more space than formerly, but the activity was so great at the time of our visit that the western wall was never visible to us, owing to the veil of steam and sulphurous vapour rising apparently from a great number of fumaroles. In the old lake-bed a new fumarole had built itself a distinct little crater, and, though emitting only

FIG. 3.—Interior of crater on White Island.

a comparatively small quantity of vapour, was making a noise suggesting fierce activity below, and about every five minutes attaining a maximum of violence with produced noticeable tremors of the crater-floor.

With all modesty I advance the following theory of the sequence of events, which seems to me to best fit in with things as we found them a month after the outbreak. First, a heavy cliff-fall, due to chemical disintegration of the towering cliffs immediately overlooking the principal old fumaroles, B, B, in the sketch-map. The steam thus pent up for a time—possibly some hours—finally burst forth with tremendous force, instantly turning the debris of the slip or fall into boiling mud, and hurling it, like one of Waimangu's crooked shots, to the east end of the crater, where in falling it broke down all before it and carried the debris into the sea. Next, the concussion and continued shakings while this eruption lasted brought down other falls from the crater-cliffs, masses of debris from which would run out of their own weight far on to the crater-floor,

and in some instances be helped in onward movement by the mud-stream, by then probably only flowing sluggishly down the crater-floor towards the sea.

Just before Christmas, 1917, I was weather-bound in a small vessel for twenty-four hours in East Bay, the island being at that time most unusually quiet, with no vapour to obscure the view. The occurrence of immense falls from the crater-walls into the crater was thus unmistakably plain, and one such fall, from the south-western wall, I estimated, by eye-judged measurements, could not be less than half a million cubic yards.

Lately there have been several statements in the Press that a blowhole had broken out on the island in a new place, the impression conveyed being that it was quite distinct from the old crater. A photograph taken by Mr. Knight, of Whakatane, recently, and published in the *Auckland Weekly News*, however, sets the question at rest by showing that the new fumarole is situated somewhere near the 1914 vent, but farther to the eastward still, along the crater-floor, possibly about the eastern margin of the old lake-bed.

FORMS AND FREQUENCY OF ACTIVITY.

Since the disastrous eruption of Rotomahana-Tarawera, in 1886, which greatly stimulated my interest in volcanic and seismic matters, I have kept such watch thereon as the affairs of everyday life would allow, and have noted more particularly the doings of White Island during the last sixteen years. Normally it can be seen steaming gently at any period of the year, but, owing to atmospheric conditions, this is more noticeable during the winter months, and on these occasions the steam-cloud may rise to perhaps 2,000 ft. or 3,000 ft., or merely just reach above the crater-walls.

At times, however, it is in much more active mood, and this is shown in one or other of two characteristic forms, or a combination thereof. One form is an unusually great volume of steam, continuously ejected for hours, or even days, consecutively; the other is great force for brief periods. At such times a column of steam may rush up in a few minutes to 6,000 ft. or 9,000 ft., and vanish as quickly as it rose, to be sometimes followed by others at brief intervals. Such a one I noticed about 4 p.m. on the 20th May of this year, but before I could adjust the theodolite to get its altitude it was gone. I estimated its height, from previous experience, at 8,000 ft.

It was my good fortune, on Sunday, the 23rd July of this year, to measure the finest display I have yet seen the volcano make. It was a clear, almost dead-calm day, and activity commenced quite early in the morning, steam being emitted both in great quantity and at times with great force. I began taking readings with the theodolite before noon, and continued till 1.20 p.m., when by far the finest shot I have ever seen went up, the height working out at 9,984 ft. above sea-level at the island, over 600 ft. higher than any previous measurement. After this both force and volume steadily declined. This display followed on several days of unusual activity.

As an appendix to this article will be found a list of notable displays by the island, which I have registered; and, though I hesitate to attach much importance to any deductions as to periodicity that might be drawn from this list, it is perhaps worth noting that of the twenty eruptions

observed, one-quarter occurred in the month of May, and one-fifth in October, while December, January, and February were blank.

Perhaps I should mention here that though at various times rumours have been set afloat, and even mention made in the Press, of flames, fire, and light being seen on or over White Island at times, at night, and "black smoke" by day, I have never managed to see any of these phenomena myself, and on more than one occasion when I have investigated such statements a much simpler and less sensational cause was discovered for the assertions made.

In conclusion, I wish to disclaim any scientific knowledge in this matter, being neither geologist nor chemist, but just a very interested layman, who has endeavoured to set down carefully and accurately the results of many years' observations, in the hope that they may be of some slight help to those better qualified to speak on such matters.

APPENDIX.

List of Occasions when Special Activity was observed to exist at White Island; with Measurements of Height to which Steam Columns rose, and other Notes thereon.

1886, Oct. 8, 10 a.m.: 7,550 ft.

1887, June 3: 6,600 ft.

1887, Nov. 3: 7,550 ft.; lasted half an hour.

1906, Oct. 9, 10 a.m.: 8,080 ft.

1909, Mar. 22, 12 noon to 1 p.m.: 5,430 ft.

1909, July 15, 11.30 a.m.: 6,525 ft.

1911, Oct. 10, 12.30 p.m.: 6,213 ft.

1913, Aug. 29, 1.30 to 3 p.m.: 8,666 ft.

1914, May 26, 11.20 a.m.: 9,020 ft.

1914, Sept. 10 (on or about): Great mud-eruption in crater, believed to have taken place on night of Sept. 9–10, when ten workers on the island lost their lives, and all buildings and plant were destroyed and swept into the sea. No observations made.

1914, Oct. 3, 12.15 p.m.: 6,218 ft. (NOTE: Four days later, Oct. 7, at 6.45 a.m., a severe earth-tremor was felt at Tauranga and many other parts of the Dominion, particularly on east coast, where much damage was done about Tokomaru Bay; followed by others at intervals for six weeks).

1915, Aug. 28, from noon: Great volumes of steam for some hours, to 5,000 ft. and 6,000 ft.

1916, May 25, 3 p.m.: 9,371 ft.; very solid column lasting two hours.

1919, May 11, 1 p.m.: 6,218 ft., a little later 7,000 ft.; great volumes for some hours. Been unusually active for some days.

1920, Aug. 18, 11 a.m.: 9,206 ft.; great volumes continued to rise till too dark to observe.

1921, April 30: 6,000 ft. to 8,000 ft.; several hours.

1921, May 4, 1 p.m.: Very rapid shot; approximately 8,700 ft.

1922, May 20, 4 p.m.: Rapid shot; estimated 8,000 ft. (NOTE: Had been intermittently active since May 12, when severe earthquake occurred at 7.45 p.m. about base of Mount Edgcumbe, with tremors following till past midnight.)

1922, July 19–23 inclusive: See text above. On 23rd, at 1.20 p.m., 9,984 ft.

A REVISION OF THE GENERIC STATUS OF SOME NEW ZEALAND DIPTERA.

By J. R. MALLOCH, Washington, D.C., U.S.A.

IN working over a large number of New Zealand Diptera sent to me for that purpose by Mr. Morris N. Watt and Mr. C. Fenwick I have discovered that many of them have been placed in wrong genera by previous workers. These errors are largely to be laid to the fact that the generic disposition of the species was almost invariably arrived at from a study of existing works on the order and without either previous experience in the order or the opportunity to examine types of these genera. I have erected in this paper three new genera for the reception of some of these wrongly placed forms, and hope that the data included in doing so may enable workers to recognize these with certainty. The types of all new species will be returned to the sender for deposition in the Dominion Museum or some other collection where they may be available to New Zealand workers.

PILINASICA gen. nov.

Generic Characters.—Belongs to the Eristaliinae, family Syrphidae, having the vein R_{4+5} deeply looped into the cell R_5 and the femora all with a patch of microscopic black decumbent setulae on their anterior surfaces at base. The wing is as in *Helophilus*, but the eyes in both sexes are widely separated, though angularly approximated in front of anterior ocellus in male, and the scutellum is much swollen, with two small humps above, beyond which it is precipitous. The presence of a tuft of fine hairs in middle of the epistome projecting over the mouth is the most striking differentiating character, and one which I have seen in no other syrphid.

Genotype: *Syrphus cingulatus* Fabricius.

I have seen this species from Kinloch, Paradise, and Eglinton (C. Fenwick).

Hutton placed this species in *Helophilus* in 1901, removing it from *Eristalis*, in which he had placed it in 1881, but he suggested that it might belong to *Mallota*. Miller in his recent paper on the family in these *Transactions*, 1921, page 315, placed it in *Mallota*. But there are so many characters that preclude its being accepted as a *Mallota* that I have erected the above genus for its reception.

HUTTONOMYIA gen. nov.

Generic Characters.—Belongs to the family Helomyzidae. Frons with two pairs of strong orbital bristles in normal position; ocellars strong; arista subnude; third antennal segment a little longer than wide; face concave in profile; cheek not half as high as eye, with one strong vibrissa. Mesonotum with three, rarely four pairs of dorsocentral bristles; humeral and presutural bristles present; mesopleura without strong bristles, bare or hairy; prosternum with one pair of bristles and many fine hairs; a weak hair above fore coxa; scutellum with hairs. Mid femur with a series of short bristles on apical half of anterior surface and one long bristle at apex on posterior surface; mid tibia with three or four long apical ventral spurs, and two very long dorsal bristles at about one-fifth from apex. Auxiliary vein very close to first, the latter ending in costa about midway between inner cross-vein and base of second vein; costal thorns short but distinct.

Genotype: *Helomyza scutellata* Hutton.

The peculiar armature of the mid femur and tibia, the close proximity of the auxiliary vein to first, the hairing of the prosternum, and the very weak propleural bristle serve to distinguish this genus from its allies.

I have so far seen no species of *Helomyza* from New Zealand.

HELOSCIOMYZA Hendel.

Generic Characters.—Belongs to the family Sciomyzidae. Head as in *Sciomyza*, the antennae not elongated, third segment short and rounded, arista subnude. Each orbit with two bristles which are rather closely placed, the anterior one not proximad of middle of frons; frons not channelled; face almost vertical. Mesonotum with two pairs of postsutural dorsocentral bristles and one strong pair of prescutellar acrostichals; propleural bristle long and strong, with several hairs at its base; mesopleura bare; sternopleura with two bristles above and the disc with numerous short hairs. Costal vein with a series of widely separated bristles which are much longer than the diameter of the vein; first posterior cell narrowed apically.

Genotype: *Helosciomyza ferruginea* Hendel.

Tetanocera rara Hutton belongs to this genus. I have seen no true *Tetanocera* from New Zealand.

The genotype was described from Victoria, Australia, and is similar in colour to *rara* Hutton, but is only about 5 mm. in length.

I have two species of this genus before me, neither of which I believe to be Hutton's species. The species may be separated as stated below:—

KEY TO SPECIES.

1. Large species, 9·5 mm. in length; apices of mid and hind femora and of hind tibia dark brown .. .. *rara* Hutton.
   Smaller species, not 8 mm. in length; mid and hind femora and tibiae not darker at apices than elsewhere 2
2. Veins 3 and 4 very conspicuously convergent apically; mid and hind femora with dense short black bristles apically on ventral surfaces; the series of short spines along the anteroventral margin of basal segment of hind tarsus uniform in strength, all sharp; the small rounded prominence at middle of upper margin of pteropleura bare .. .. *spinicosta* n. sp.
   Veins 3 and 4 slightly convergent apically; mid and hind fermora densely short-haired ventrally from base to apex; the series of short spines along the anteroventral margin of basal segment of hind tarsus uniform from tip to near base, the two basal spines much stouter and with blunt tips; the small rounded prominence at middle of upper margin of pteropleura with some setulose hairs .. .. *setuligera* n. sp.

Helosciomyza spinicosta n. sp.

Male.—Tawny, the frons paler, reddish-yellow, the face yellowish. Lateral margins of mesonotum whitish-grey; pleura with a median longitudinal brown stripe, pale grey above and below brown streak. Dorsum of abdomen brownish. Legs pale tawny, the apical tarsal segment fuscous. Wings yellowish, the cross-veins hardly suffused.

Frons with black hairs. Dorsum of thorax rather densely short-haired; scutellum bare, subtriangular, with 4 bristles. Apices of abdominal tergites with strong bristles; fifth sternite transverse apically; hypopygium small. Hind tibia with a series of short setulae on at least the apical half of anterodorsal surface.

Length, 7·25 mm.

Type. Dunedin, 20th November, 1921 (M. N. Watt).

Helosciomyza setuligera n. sp.

Male.—Similar to the preceding species, but the outer cross-vein and apex of wing more distinctly clouded. Differs as stated in synopsis, and in having the scutellum with microscopic setulose hairs on sides and soft hairs below. In other respects as *spinicosta*.

Length, 6·5 mm.

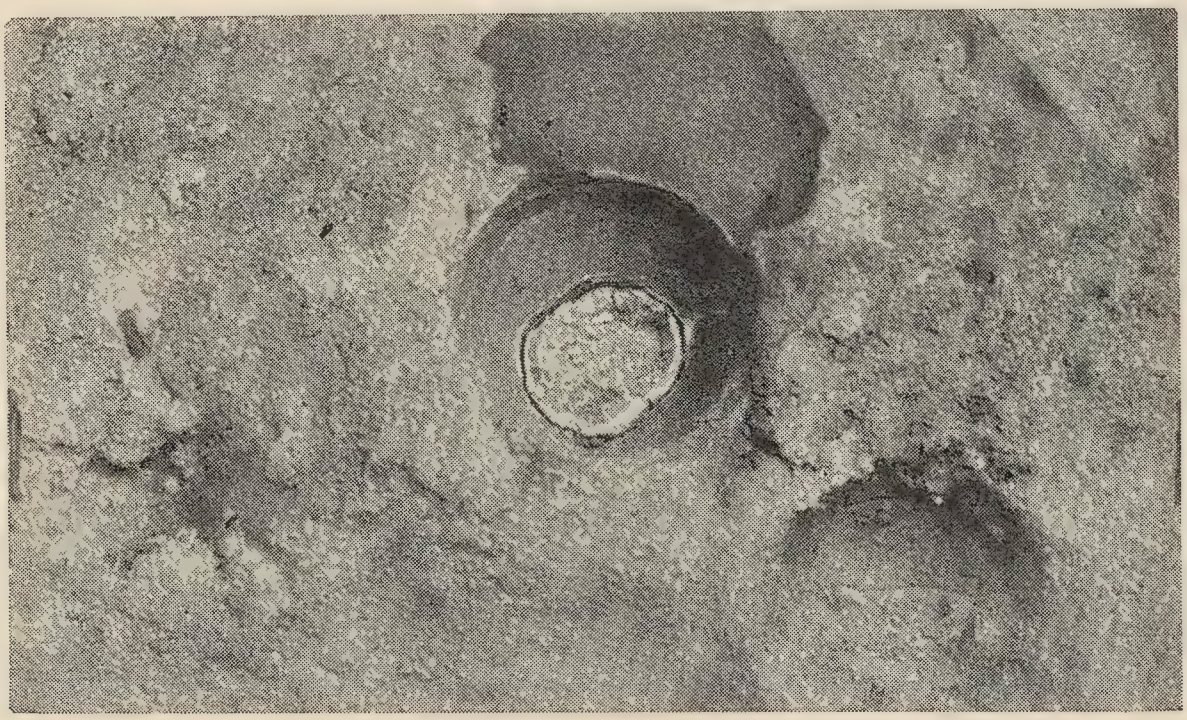
Type. Paradise (C. Fenwick).

CONCRETIONS AT HUNUA COAL-MINE, AUCKLAND.

By J. A. Bartrum, Auckland University College.

During a recent excursion with a party of students the writer visited for the first time the coal-mine near Hunua, in the vicinity of Papakura. This has been worked intermittently for many years, but when visited was temporarily closed. In the few minutes available some concretions were collected from the overclay immediately above the coal, and these show unusual features which may be of interest to readers of this journal.

The concretions are of hard, compact, impure ferrous carbonate (siderite) in very minute crystals, and vary considerably in shape and size; those observed were a little flattened parallel to the bedding-planes of the containing bed, and averaged about 5 in. in diameter. Those lying about the surface were pitted by symmetrical, almost hemispherical hollows



Structure of a Concretion occurring within Siderite Masses at Hunua Coal-mine, Auckland.

averaging perhaps $\frac{1}{2}$ in. in diameter. Other hollows were more elongate, but very generally symmetrically rounded. In the siderite masses which had not long fallen from the soft overclay in which they were formerly embedded the original filling of the hollows was often still retained. It furnishes the chief interest of this note, for it consisted of included bodies which may be regarded as concretions of a somewhat unusual type. All examined had a core of rather incoherent greensand—a material much coarser in grain than any of the beds immediately associated with the coal—upon which was a sharply distinct coating of fine white clay varying from a mere film to $\frac{1}{12}$ in. in thickness in different individuals. Some of the greensand cores contained smaller fragments of dark-grey shale. Drying unfortunately produces very rapid disintegration of these small "concretions," and the illustration therefore depicts merely the small remnant of one of them nestling in its appropriate hollow.

In the writer's opinion the only feasible explanation of origin is to regard the greensand cores as worn and removed from some previously deposited bed of such material. Their transport by rolling to the area where now found was evidently the result of conditions temporarily different from those obtaining during the deposition of the rest of the overclay in which they collected. In passage they accreted a coating of fine white clay from

a surface of this upon which they were rolled, and hence can broadly be considered concretions.

Similar accretion of mud around fragments of scoria has been noted by the writer in some of the tuff-cones of the Auckland district. Here this results almost certainly from the rolling down a slope of the scoria-fragments amidst adhesive finer ejecta of the eruptions which gave birth to the cones. This actual process of formation has been elsewhere observed and recorded by other observers.

The relationship of the smaller concretions to the major ferrous carbonate ones has yet to be considered. The line of demarcation between both is very sharp. Several of the larger siderite masses were broken, and showed no signs of inclusions in the interior portions. A fact then requiring explanation is the limitation of the small concretions to the surface portions of the larger. The writer suggests that perhaps the growing force of the crystallizing ferrous carbonate sufficed to effect this distribution by pushing the extraneous smaller concretions outwards as crystallization proceeded. There is no evidence that the siderite masses had other mode of formation than the contemporaneous one usual when they occur in association with coal-beds.

NATURAL-HISTORY NOTES.

Occurrence of the Bullfinch in New Zealand, by the Hon. Geo. M. THOMSON, M.L.C., F.N.Z.Inst.

As mentioned in *The Naturalization of Animals and Plants in New Zealand* (p. 175), the only recorded instances of the introduction of this conspicuous bird into this country were in Nelson in the early days of settlement, and in Canterbury in 1875. In neither locality did the species increase and become feral. But in later years it has been reported from such widely separated localities as Hawke's Bay and North Taranaki, though the latter identification wants confirmation. Recently I have received further information on the subject.

Mr. H. Guthrie Smith, writing on the 2nd June of this year, sends me the following:—

"In regard to the bullfinch, I have heard of them for years about Woodville, and Mr. J. L. Handyside, of Akitio, and Mr. Bolton, of Woodville, tell me the bird is to be seen in that district. Neither, however, has yet been able to procure a specimen for me. Mr. Hutchinson, of Rissington, writes, in July, 1905: 'Twelve months ago, more or less, I remember telling my son I had seen that day the first bullfinch I had ever come across in New Zealand. Where it was I cannot remember, but think it was at Rissington, and I think there was a pair, but was not certain about the second bird. Other small birds were about, and I remember expecting to see them again, but never did.' Mr. Francis Hutchinson, jun., writes: 'I was staying at Rotorua in the early part of November, 1899, and went seventeen miles up the Auckland–Rotorua Railway to Mamaku. In a bush clearing there, on a sawmill tram-line, I saw a bird which I have no hesitation in saying was a bullfinch. He was in the company of a crowd of sparrows, and I saw no others of his own species with him. He was much tamer than the sparrows, and may have been an escaped pet. A few days before I had seen a pair of birds on Ngongotaha Mountain, a few miles from Rotorua, that I suspected to

be bullfinches, but could not get a close enough sight to be at all certain of them.' Mr. Burridge, of Napier, tells me of a hen bullfinch, almost certainly an escapee, in Mr. R. D. D. McLean's garden. Finally, there were the pair I saw at Tutira in 1902. I still hope to get specimens from southern Hawke's Bay, but they must be very rare, for the bullfinch is unmistakable and not to be confused with any other species. I have seen scores and hundreds of the males while shooting in Scotland. There, in Argyle, they haunt the little birch glens, their black-and-red colouring looking lovely against the white of the snow-clad moors."

The other communication is from Mr. E. Marryat, organizing teacher under the Otago Education Board, who informs me that bullfinches are found at Papatowai, in the Catlin's district, in South Otago. He has himself seen the birds several times, and his observations have been verified by others. Writing to me on the 16th July he says :—

"The bullfinches are still there. I showed a picture of one to the children, and about half the school (roll 28) had seen the bird. One visited the playground during the week. . . . The residents whom I had the opportunity to ask had also seen the bird. One boy had seen one recently in the open bush near the Tahakopa ford, about two miles from the school. I conclude, therefore, there are only a few about."

It is probable that in all the localities recorded the birds had escaped from cages, and, being only partially wild, had not strayed far from the place of liberation. It will be interesting to find whether they increase in numbers.

Records of Albino Kiwi, by H. Hamilton, Dominion Museum.

It has long been recognized that the New Zealand avifauna has extreme tendencies towards albinism. Buller in 1888 recorded thirty-four species of native birds showing more or less pronounced albinism, and no doubt this list could be enlarged at the present day. So far no good and sufficient reason has been given to account for this tendency in New Zealand birds. In the case of the giant petrel, or nelly—*Macronectes giganteus* (Gmelin)—it has been demonstrated that albinos proportionately increase in numbers as the Antarctic Continent is approached. As regards albino kiwi, records show that more have been taken or seen in the North Island than in the South.

The old-time Maori must have found the albino kiwi to be fairly common, judging by the numerous cloaks in existence containing feathers of this bird. Some cloaks in the Dominion Museum are bordered and striped with white feathers representing the pluckings from several birds. All the cloaks I have examined are composed of the feathers of *Apteryx australis* (North Island).

Recently a splendid specimen of an albino *Apteryx australis* was captured near Eltham, Taranaki, and eventually acquired by the Dominion Museum. The bird, an adult male, was a pure albino, the feet and claws being ivory-white. A photograph, taken after the bird had been mounted, illustrates this article.

As far as can be gathered from records, the following albino kiwi are in existence. In the Canterbury Museum there is a partial albino of *Apteryx australis* in which the crown and sides of the head and throat, the whole of the foreneck, and in front of the thighs, are yellowish-white. The Australian Museum, in Sydney, possesses a fine albino of the North Island *Apteryx australis*, taken in the Taupo district in 1885, probably one of the five that Buller records as having been taken by the Maori on a hunting expedition during that year. In the year 1913 the Tourist Department at Rotorua obtained from the Taharua district, near Taupo, a live albino kiwi, probably *Apteryx australis*. This bird was taken to Little Barrier

Bird-sanctuary for liberation, and recent reports from the caretaker would tend to show that the bird is still alive there.

In response to my inquiry as to the facts concerning the capture of this bird, Mr. W. Cobeldick, Tourist Department Ranger at Rotorua, gave in addition the following interesting observation :—

" Owing to the habits of the kiwis being almost wholly nocturnal they are rarely seen in the daytime, though on very wet days in heavy forest-growth I have seen them. On such a day in September, 1918, I had carried a can of trout-fry from the shore of Lake Waikaremoana for liberation in the upper waters of the Hopuruahine River, above the waterfalls. Returning about 4 p.m. along the track, which is very soft with many little springs rising in the bush, I noted beneath some trees that a kiwi had been feeding since I went along in the morning about 11 o'clock. The footprints and the peculiar holes left by the bird as it plunges its long beak into the

soft soil were very fresh. I walked off the track along the swamp into the heavier bush and got quite close to the kiwi, which was a black one, but not of great size. This is the only instance of melanism I have seen of the kiwi, and the light was bright enough to show that it was not a brown one, although brown ones have been seen in this locality. It is hard to record authentic instances of albino kiwi, as they are mostly killed by dogs in the bush, and the feathers are highly prized by the natives for working into mats (cloaks) or kits."

I am indebted to Mr. Cobeldick for this extract from his store of knowledge concerning the habits and distribution of New Zealand birds.

The little grey kiwi (*Apteryx oweni*) has also been found as an albino, for the Otago University Museum has a specimen probably from the west coast of the South Island. Buller records also that Mr. Smythe, a Dunedin taxidermist, had in his possession an almost perfect albino of this species, obtained from Martin's Bay.

It will be seen, therefore, that comparatively few albino kiwi are in existence in museums and collections. With the natural (or unnatural) decrease in our avifauna, it follows that fewer specimens are likely to be met with in the future. The writer would be pleased to hear of any further specimens of albino kiwi in existence.

REVIEWS AND ABSTRACTS.

The Fishes of New South Wales, by Allan R. McCulloch, Zoologist, Australian Museum, Sydney. Quarto, pp. xxvi, 104, with 43 half-tone plates. Price 5s. Published by the Royal Zoological Society of New South Wales, Box 2399, G.P.O., Sydney.

This volume is the first of a series of Australian zoological handbooks planned by the Royal Zoological Society of New South Wales. The society is to be heartily congratulated upon its first venture, both in securing so well known an author to carry out the work, and also in issuing it so cheaply, the sale price being actually less than half the cost of printing each volume. This has been possible through the building-up of a special fund to be used for the publication of the handbooks, which it is felt should be issued at a price within reach of everybody. In putting the first volume on the market at so reasonable a rate the society has laid everybody at all interested in fishes under a deep debt of gratitude. We may venture to hope that the society's resources will be able to stand the strain which the issue of other fine handbooks will put upon them, and that equal success may attend their publication.

Mr. McCulloch is well known not only for his expert knowledge of Australian fishes, but also for his remarkable ability as an artistic and scientific draughtsman. Most of the numerous figures in the forty-three excellent plates are clearly of his own creation, being reproductions of larger wash drawings from his brush. They are all equally good for the purpose of identifying the species. Where a genus contains a number of similar species the author has wisely illustrated only the one type; those not figured can be determined from the clear and simple generic and specific keys in the body of the work. The plan of the book is that of a check-list, with keys to every division from classes down to species. The scheme of the keys and their method of numbering are good; and we should imagine that, with the diagram and glossary to help him, even a beginner in zoology would find little difficulty in determining any species of fish which he might want to identify.

It is interesting to note that the author records no less than 588 species from the coast and rivers of New South Wales, being roughly one-third of the total found around and in Australia. Many of these, of course, only secure inclusion as the result of one or two records. For all the commoner varieties the author gives the vernacular as well as the scientific name, and an index to the former is also a very useful feature. Measurements of each species, and short notes on the habits of many of them, are also given. The scientific nomenclature is brought up to date, and full synonymy given for each species.

One cannot but be struck with one fact for which the author is in no way responsible. According to the very modern classification adopted, the 588 species are contained in no less than 371 genera, 162 families, and 19 orders! This gives an average of little more than one and a half species to a genus, and somewhat over two genera to a family! So the modern vice of "limitation of families" is clearly not confined to the human race itself, but has even affected zoological classification. One begins to wonder whether this kind of classification is going to serve any useful purpose;

would it not be better for us all to fall into line and cheer the modern "splitters" on, so that they could more quickly "go the whole hog," and accomplish the course which they have already nearly half completed? That is to say, let us be done with it, and let each species have a family and genus of its own! Entomologists have long been complaining of their "splitters"; let them now study fishes, and then call upon "whatever gods there be" to help them when the half-million species of insects are classified along the same lines as these.

R. J. T.

Dominion Museum Monograph No. 2, "Spiritual and Mental Concepts of the Maori," and No. 3, "The Astronomical Knowledge of the Maori, Genuine and Empirical," by Elsdon Best.

Under the heading "Thinking Brown" the literary editor of the *Timaru Herald* reviews, on the 5th August, the Dominion Museum Monographs as follows:—

"One of the most extraordinary of living missionaries—a canny and yet fanatical Scot, buried for a quarter of a century in 'the long grass' of Central Africa, and loathing everything in civilization but its Bible and its God—wrote a book a few years ago called *Thinking Black*. So also the profoundest of living students of the Maori, Mr. Elsdon Best, is in process of writing a book which should be called *Thinking Brown*. Dan Crawford's method with the African—we should perhaps say his achievement—was to get underneath the latter's skin, into his brain-pan, behind his organs of sense and his nerve-centres of thinking, feeling, and willing, and to write from there. Mr. Best's contact with the Maori is no less intimate and subtle. He does not explain the Maori from the outside: he rather becomes a Maori spiritually and then explains himself.

"And the result is a series of profoundly interesting monographs now being issued by the Dominion Museum. No. 1, reviewed in these columns some time ago, was *Some Aspects of Maori Myth and Religion*. Nos. 2 and 3, now also to hand, are *Spiritual and Mental Concepts of the Maori* and *The Astronomical Knowledge of the Maori, Genuine and Empirical*. Mr. Best's method is to take terms in common use by the Maori and to explain how the Maori intends them, how he evolved them and the beliefs which they now imply, and to convey to the average unobservant pakeha what a remarkable capacity for abstract thought the Maori had developed before he ever saw a white man. Perhaps the most interesting feature of Monograph No. 2 is the revelation of a native belief in the possession by man of a portion of the Divine nature—an astonishing refinement of thought for a neolithic people. Monograph No. 3 shows that all Maoris knew the principal stars, and that some had made a close study of them; that, in spite of their isolation, they became 'the foremost neolithic navigators of the grey ages'; and that in all their wanderings—'the long, long voyage that lasted for so many centuries'—it was the Shining Ones that not only guided and protected them but would one day also lead them back to 'the long-lost but ever-loved homeland.'

"These Monographs, which are admirably printed and produced, can be obtained from any bookseller, or direct from the Dominion Museum, Wellington. The New Zealand price is 1s. for No. 2 and 1s. 6d. for No. 3, post free."

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No. 4.—Maori Division of Time. 1s., post free.

The above have been written by Mr. Elsdon Best, F.N.Z.Inst., the well-known authority on Maori life, institutions, and customs.

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SCIENCE AND MANUFACTURE.*

By GEO. T. BOOTH.

WHEN we New-Zealanders think of industrial production we have chiefly in our minds the produce of the farms, the mines, the forests, and so on. That is naturally the case in a new country such as this is. Indeed, in any country, primary production is of the first importance. But it may be asserted with considerable confidence that no country ever became great by primary production alone.

It would seem that human society, whether in small units or in large, depends for its proper development upon diversity of occupations, and that it is necessary to establish and maintain some sort of equilibrium in the social unit corresponding to the balanced parts and members of the human body or other living organism. We are, very really, members one of another; and as the human body needs the head to serve the hands, and the hands the head, so the social organism depends, for its complete satisfaction, upon a diversity of creatures, of interests, of activities, all bound together for mutual service.

So it comes about that primary production is only the initial step, the first in order of time and of importance, of the material functions of an organized State. Manufacture, trade, transportation, and a thousand allied activities follow as a matter of course, if not of necessity.

Development has taken that direction in New Zealand as elsewhere. It is just over one hundred years since a plough was first put into the soil of this country; little more than half of that time since settlement on a wide scale began. But even in that short period the balancing process has made considerable advance.

I am not going to bother you with figures, which you can look up in the official records if you so wish, but if you do I fancy you will be surprised

---

* An address delivered before the Philosophical Institute of Canterbury on 4th October, 1922.

to find to how large an extent secondary industry, or what we understand as manufacture, is already contributing to the wealth of the Dominion. In this respect New Zealand is but treading in the steps of other and older countries. Germany, for instance, was mainly an agricultural country, and a poor country, in the middle of last century. Not until she applied herself, with her customary thoroughness, to the development of secondary industry did she grow rapidly in wealth and national power. In the light of recent events you may regard Germany as an unhappy example, though you may rest assured that, whatever may have happened to military Germany, we have not heard the last of industrial Germany by a very long way. But the American Commonwealth is another and perhaps a more acceptable case in point. Up to the middle of last century it depended mainly upon primary production, but since then its manufactures have developed amazingly, and made it in sixty or seventy years the greatest industrial country on earth, and the richest. Thirty-one per cent. of its population are engaged in manufacturing, and account for two-thirds of the total wealth-production; the remaining one-third being contributed by agriculture, mining, forestry, fisheries, and the like.

Perhaps it may be possible for a country to become over-industrialized, but New Zealand is not in danger of that sort, nor likely to be. She is far from having reached the limit of her possibilities in primary production as yet, and her secondary industries have hardly emerged from their swaddling-clothes.

Now, the secondary industries depend to a large extent upon the primary, and if I am asked to say where I think a beginning should be made in bringing science to the service of manufacture I should say that the right place is at the beginning. Agriculture is the foundation. Our farms must be efficient enough to provide food for a population much larger, perhaps many times larger, than the present, before manufactures (with one or two possible exceptions) can be developed to any considerable extent in New Zealand. For economical secondary production under modern conditions there must be a home market large enough to justify operations on a reasonably large scale, in specialized plants.

But our agricultural production can undoubtedly be intensified and increased to the requisite extent; and it must be, for in no other way can we hope to pay off the heavy burden of debt, our heritage from the war. With the help of science it can be done. Scientific methods applied to agriculture, directly and indirectly, yield wonderful results. By such means Germany—to cite that unfortunate country again—increased the production per acre of her soil by 50 to 100 per cent. in the thirty years or so preceding 1914.

Our meat-freezing industry has indirectly caused many more than two blades of grass (or their equivalent) to grow where only one grew before. I remember one of Canterbury's most progressive and most highly respected pastoralists asserting that we could never hope to maintain a continuous export of a million carcases of lamb and mutton per year; that it would be impossible to carry the necessary flocks. That was not very many years ago; but our exports have passed that point long since, and now amount to several millions per year, the direct result of science applied to agriculture.

We boast, and not without good reason, of the wonderful development of the dairying industry, but it is safe to say that our average dairy herd

does not yield one-third of the best possible—that is to say, with scientific breeding and selection of dairy cattle the production can be increased threefold or more, without increasing the stock by so much as one head.

I venture to assert that on the average the farm-land of New Zealand can be made to produce several times as much as it is now producing. I am not unmindful of the splendid work science has already done and is doing for agriculture, in soil-survey, agricultural chemistry, control of diseases and natural enemies, selection of seeds and stock, and so on; nor for the secondary industries allied to agriculture, as in the preservation of meat, utilization of by-products, treatment of milk and its derivatives. But what has been done is only an earnest of what will yet be done as the value of such work comes to be recognized and appreciated. And with the development of agriculture, population will increase and secondary industries will take on ampler growth.

There are other primary industries, however, with which manufacture is intimately concerned. Power is a necessity in every factory, and is still derived to a large extent from coal, burned under boilers or as gas. Nature has endowed New Zealand with extraordinary wealth in coal, but it is being wasted wantonly. An American authority has stated recently that of every 2,000 lb. of coal in the seam only about 76 lb. are finally converted into mechanical energy. The other 1,924 lb. are lost in mining, transportation, and handling, in gases going up the chimney-stack, and so on. 96 per cent. lost, 4 per cent. used! In all probability the figures for New Zealand would not compare favourably with these, and even in this little country the waste of wealth under this heading must be enormous.

Economies in the use of coal are being effected from time to time—by burning it in the form of dust or mixed with oil; by means of improvements in furnaces or gas-producers; by condensers and economizers of steam, more efficient engines, and so on. But these, after all, are only half-measures. It is common knowledge that coal contains a wonderful variety of valuable constituents which can be saved by scientific treatment but are lost in burning, but we go on burning it just the same.

Much the same is true of our timber resources. A start has been made in scientific forestry, but not until after millions of pounds' worth of timber has been wilfully destroyed, involving incidentally the destruction of much of the natural beauty of the country. But scientific forestry will not save the full value of the remnant unless it embraces in its scope the treatment of the timber during and after removal from the forest, as only about one-third of a tree is converted into building-material, and the remaining two-thirds are still available for other purposes. Every year we buy thousands of pounds' worth of paper from Norway or Canada or elsewhere, which is made from wood-pulp. Half the silk of commerce is made from wood, and even the dust from the saws is convertible, by mechanical and chemical means, into useful and valuable products. But we burn the off-cuts and the sawdust to get them out of the way.

Before parting company with agriculture it is worthy of note that motor-fuel, a commodity of immense value in the modern world, is being successfully produced from waste potatoes, grain, fruit, molasses, and various shrubs and roots; that unmarketable apples, oranges, and lemons are being turned to profitable use. Seemingly, we have found the philosopher's stone without knowing it. By appropriate applications of science,

not the base metals merely, but all the litter, and rubbish, and noxious accumulations that are now an embarrassment can be turned into gold. I do not wish to labour this question of industrial waste unduly, but have referred to it as indicating wide fields for scientific activity. It is of special interest, however, for the reason that so many industries are dependent upon, or feed upon, the waste or by-products of antecedent industries, and so it is cognate to the subject we are supposed to be considering.

I referred a minute ago to mechanical power as being vital to the carrying-on of many secondary industries. Science has done wonders in this connection in making the development of water-powers possible, in electrical transmission, and in many other ways. We may have to wait a while longer before intra-atomic energy is available for our factories, but a vast amount of scientific work is being done in the production and distribution of cheap and trustworthy motive power; and we may safely predict that much more will be done, that new industries will spring up in consequence, and that the wealth-producing capacity of the Dominion and of the world will be enormously increased as the years go by. There is perhaps no line of effort that contains richer promise for the material progress and well-being of the race than this.

But now to come to closer quarters with the subject of "Science and Manufacture," to which all this has been leading up: The manufacturer has three problems, or three sets of problems, always in process of solution—or otherwise, as the case may be—disregarding the minor problems incidental to any individual business. The first relates to raw materials and mechanical appliances. The term "raw materials" is not quite correct, as practically all material reaches a given factory after having passed through at least one antecedent process, and probably more than one. The boot-manufacturer, for instance, draws his supplies of leather from the tanner or the finisher, his grindery and linings from other sources. The manufacturer of clothing is supplied with material by the woollen or cotton mill, the thread or button maker, or whatnot. Hardly any industry stands quite by itself, but is a link in a chain of processes, the finished product of one becoming the raw material of the next in order. Each manufacturer must watch the markets and arrange for a continuous supply of materials, in the right qualities and quantities and at the right prices, suitable for his trade. He must watch the market on the other side too, and arrange his schedule of production to meet as nearly as may be the requirements of his customers.

Then, he has to maintain his mechanical plant in such condition that its operation shall earn him a profit. The order of operations must be planned and the work routed from department to department and machine to machine, with efficient inspection and check at each stage, all to the end that space, and time, and energy (human and mechanical) shall be used to the best possible effect, waste and loss avoided, and both quality and quantity of product kept up to the desired standard. The organization of a factory, even a small one, is not as easy as A B C, and cannot be carried out successfully by rule of thumb.

The manufacturer, in the nature of things, is sympathetic to science. He cannot but be, because he has to be a bit of a scientist himself. He has to study cause and effect, and use carefully designed means to obtain particular results. He may know but little of science in the abstract. He may not think of it in terms of the study or the laboratory. More likely his regard is centred upon its practical daily applications to his

material needs. But he realizes its value nevertheless, and is well enough aware that back of the practical application there is the study and the laboratory, the life spent in pure research, the patient, laborious, unselfish devotion to the pursuit of knowledge for its own sake. If he were inclined to criticize at all I think it would be on the ground that so much original work of the kind is being done, so many discoveries being made, and yet so much that might be used beneficially is inaccessible to him and his fellows. I think he would say something like this: "Let the student who prefers and has the faculty for original research work get on with it by all means. Everything depends upon him. But let us have some others helping him, working with him, not interfering but watching and studying his results—fellows who know something of our end of the job and can tell us how to make use of these discoveries." And I think that would be a very natural and proper suggestion. The scientist in his study and the manufacturer in his factory are too far apart. Not that they are unsympathetic; not that there is any lack of consideration—shall I say ?—on one side or of respect on the other, but that a link of some kind is needed to establish effective contact between them.

Scientific and industrial research should take perhaps a more prominent place in the activities of our University colleges. With a sufficiently large number of students so engaged, a natural division would probably develop between those whose bent is towards pure science and those who incline to technology or the application of science to the industrial arts. Perhaps something might be gained by establishing some sort of co-operation between the University and the technical colleges, whereby promising students from the latter could be brought into touch with the work of the former. Something must be done in this direction if the natural resources and the manufacturing industries of the Dominion are to be developed as they should be.

They manage these things better in Germany (I wish I did not have to use that name so often) and in America—better, I think, than in our own Mother-country, and certainly better than here. And I believe that if this gap can be bridged, some effective bond provided, the Dominion may be enriched beyond the dreams of avarice. I do not mean in pounds shillings and pence merely, but in everything that can contribute to the fullness and the joy of life.

The second problem for the manufacturer has to do with the human instruments of production, and is of a very different character. For its solution he needs to have a knowledge of human nature other than what he picks up in the street. The names would probably convey little meaning to him, but he requires the help of the psychologist or the psycho-physicist. Here again science is doing good work, but the difficulty is to bring it home to where it will do most good. Learned treatises are of little use to the average employer or workman; both need to be addressed in a language they can understand. Labour is a very important element in the cost of production—indeed, the most important—and its efficiency or otherwise spells success or failure. Waste of human energy is the worst kind of waste. Machinery may stand idle for a while without much loss, but not so with labour. It is of radical importance that the human equipment of a factory, from the top to the bottom, shall work smoothly, intelligently, and efficiently, and that implies that it shall work happily and contentedly. Unfortunately, forces are at work which militate against such a state of affairs, and situations frequently arise which call for

delicate handling. But on this subject I may be suspected, reasonably enough, of prejudice, so I will only repeat that both employers and employed need all the help that students of human nature can give them.

Thirdly, the manufacturer in his general administration has to deal with problems relating to finance and financial conditions. His business must be made to yield him a profit, not merely a living and interest on the money invested, but also a *surplus* sufficient to maintain it in vigorous existence; to provide for continuous expenditure on the upkeep of the mechanical equipment; for the replacement of obsolescent by improved and more efficient machinery, tools, appliances, and methods; for fluctuations in business; for changes in demand involving variations in product; and for active development.

No business can stand still; it must move forward or it will inevitably go backward. There must be growth or there will be decay. How difficult it is to ensure the former and prevent the latter is indicated by the fact that not more than about one business in ten lives ten years; and a very large proportion of the failures are due to external financial conditions.

All business is more or less speculative. A vast proportion of the world's daily transactions is almost purely so, consisting of the purchase and sale of stocks and shares or other marketable securities, on the chance of a rise or fall. Another large proportion is scarcely less so—insurance, for instance, which is little more than a systematized and glorified gamble on the chances of fire, shipwreck, accident, or death. The speculative element enters largely, though not to so great an extent, into trade, regarded as the buying and selling of commodities. It plays a relatively unimportant part in primary and secondary production, for the reason that so large a proportion of the invested capital is fixed and unrealizable so long as the business continues—as the land and stock of a farm, or the buildings and plant of a factory—and so small a proportion is fluid and capable of being turned over from month to month or year to year. Only in respect to this fluid fraction is speculative profit possible, and even so it is rigidly limited by the nature of the undertaking. A farmer cannot change over his production at short notice to catch a rising market or to dodge a fall, neither can the manufacturer.

The farmer goes on the assumption that the products of his land, in their proper rotation and proportion, will bring in a certain revenue from year to year over and above sufficient to cover his outgoings. The manufacturer does the same. In both cases production is the main function, and trading is only incidental; and as regards the latter, both are at the mercy of the markets. What concerns them both is that they may rely upon being able to sell their wheat or wool or boots at prices which will yield them a profit over and above the cost of production. They know pretty well what the cost of production is or is likely to be. They know that wheat and wool and boots will be needed. They feel entitled to expect that those who need them will be able to pay for them at rates commensurate with the cost of production.

But prices do not depend upon cost of production alone. They depend also, and to at least an equal extent, upon the buying-power of would-be consumers, which is to say the amount of money available for the purchase of wheat, or wool, or boots. What farmers and manufacturers want more than anything else is a stable monetary unit—stable, that is, in

purchasing-power—an assurance that the system of finance will be equal to the demands upon it at all times, and keep prices constant, within reasonably narrow limits, relatively to the cost of production and the world's needs.

Now, we have an almost world-wide system of finance, which has been developed through many years and was supposed to have been brought nearly to perfection. But it has not worked satisfactorily in the past, as evidenced by the violent fluctuations in prices during the last century, for instance, with corresponding alternations of prosperity and adversity. Nor in recent years has it stood the test. At the first breath of war in 1914 it collapsed like a house of cards. Governments had to step in and declare moratoria. Then followed commandeers, and controls, and subsidies, and embargoes, and floods of new money, until the world of commerce was well-nigh stupefied. The financial authorities said these schemes would never work—that the war could not last a month, and that sort of thing; but they were wrong.

Then, when the war ended, reason, taking account of the enormous destruction of wealth on the one hand and the diminished labour-power of the world on the other, said, "Production must be stimulated. We must all work harder than ever before, to make good the waste"; and, being reasonable, we set about it in great style.

But where did we arrive? Almost at a standstill. Farms bankrupt, factories shut down, millions of men idle. Why? Because of financial difficulties. Apparently the system of finance had broken down again.

The fault is not on the side of production. The world is not overfed; it is not overclothed. There is no reason in the nature of the case why production and commerce should have been reduced to such evil straits.

Now, I am not an authority, but when I say that the monetary basis of our financial system is one which was originally adopted because it "tickled the fancy of savages," I am using not my own words but those of one of the most highly respected living authorities. If the same gentleman were writing on the subject to-day he would probably have something to say about its easy adaptability to enormous international frauds—a possibility which one would think any serious student might have foreseen.

As I understand it, money was devised as a medium of exchange or barter between goods and services, a go-between producer and consumer, buyer and seller, intended to serve the convenience of both. Obviously, the quantity of money necessary for the performance of this function would be greater as transactions increased in number, frequency, and magnitude; and a system of credits and balancing was a natural development, a system which has grown to tremendous dimensions as the area of business has expanded in the modern world.

But I do not think it could ever have been contemplated that the relations between the necessities of trade on the one hand and money (or its equivalents) on the other should change. The former was to be the master, the latter the servant. It could never have been contemplated that the relation might be reversed—that money should become the master and trade the servant; and yet that is what has happened. "The average price-level is at the mercy of monetary and credit conditions" (Fisher). Money has become master of the situation, and, as such, "a source of peril and confusion" (Robertson).

And this is to be noted: there is no real profit in juggling with money or credit. Such operations are merely a waste of human energy. There is nothing to be gained by forcing prices up or down. Transferring money from one pocket to another will never make the world one penny the richer. Wealth cannot be increased by such means. Production is the only source of wealth, and there must be more and more production to provide for the world's increasing population and its increasing needs.

I have only this to add: that science can render no greater service to the world at this juncture than to discover, or invent, or devise a monetary system that will really act as a medium of exchange between buyer and seller; as a willing servant of both, not a master; and as a measure of value, not a dictator; that will hold the balance even and maintain stable relations between producer and consumer, and between debtor and creditor; that will meet all reasonable exigencies, and prevent the violent fluctuations in prices and recurrent periods of depression, and confusion, and ruin that seem inevitable under the existing system. The present system is obviously inadequate to perform the duty demanded of it, and I am loath to believe that it is beyond the wit of man to devise a better. I do not think that in any way can science do more to stimulate the development of existing industries and the establishment of new ones, and to encourage production, both primary and secondary.

A SKETCH OF THE ECONOMIC DEVELOPMENT OF NEW ZEALAND.

By J. HENDERSON, D.Sc.

THE economic growth of New Zealand has taken place in several stages, which, although they decidedly overlap, are yet characterized by distinctive features. But each is a condition precedent to the next, and a necessary link in the chain of evolution. The story of New Zealand before the advent of Europeans belongs to the realm of myth and tradition rather than to history; and so far as this brief sketch is concerned, the first stage is considered to begin with the coming of Cook, and to end in 1840 when "the Colonial Office was reluctantly compelled to add the Islands to an Empire which the official mind regarded as already overgrown."

New Zealand's trade was at first chiefly with New South Wales, from which colony in 1792 a sealing expedition was despatched to Dusky Sound. Thus began an extremely profitable fur trade which continued for over three decades, till indiscriminate slaughter so reduced the numbers of the animals that their capture became unremunerative. The ill-fated Du Fresne was one of the first to make use of the kauri, but the Sydney merchants quickly realized the value of the timber, and a lucrative trade was carried on with India, South Africa, and England. Soon also the abundance of whales along the New Zealand coast brought many whaling-ships to this region; and in the first quarter of the nineteenth century as many as a hundred ships per annum used to refit and obtain fresh food

and vegetables at the Bay of Islands. Right whales, which frequent the coast from April till September, were first caught from shore stations in 1827. Those earliest established were in the vicinity of Cook Strait, where a few whales are still caught annually; but the other stations that, within a decade, dotted the coast of New Zealand from end to end have long been deserted.

Trade with the Maoris also flourished, and early in the century the Islands became the favoured haunt of nondescript trading-schooners. "The Maoris might be cannibals, but they were eager to trade. In their forests grew trees capable of supplying first-class masts and spars. Strange weapons, ornaments, and cloaks were offered by the savages, as well as food and the dressed fibre of the native flax. Moreover, a peculiar and profitable, if ghastly, trade sprang up in tattooed heads. A well-preserved specimen fetched as much as £20. Hitherto hung up as trophies of victory in the pas, these relics of battle were quickly turned to account, at first for iron, then for muskets, powder, and lead. When the 'natural supply' of heads of slain enemies ran short, slaves, who had hitherto never been allowed the aristocratic privilege and dignity of being tattooed, had their faces prepared for the market. Sometimes, it is recorded, a slave, after months of painful preparation, had the audacity to run away with his own head before the day of sale and decapitation. . . . . It was missionary effort, however, that at length killed the traffic—and the art of tattooing along with it. Cook had found the Maoris still in the Stone age. They were far too intelligent to stay there a day after the use of metals had been demonstrated to them. Wits much less acute than a Maori's would appreciate the difference between hacking at hardwood trees with a jade tomahawk and cutting them down with a European axe."*

Soon, also, the Maori realized the superiority of the musket over his native weapons. Tribes fortunate enough to possess themselves of firearms attacked their less fortunate enemies, ate hundreds of them, and enslaved thousands; wide areas were swept bare of people. Only by procuring guns and powder could a tribe hope to survive. Men and women toiled unceasingly at procuring timber and preparing flax and garments, &c., which, together with potatoes, kumara, pigs, and even land, were exchanged for firearms and ammunition. Other imports, for the most part luxuries, included axes, knives, fish-hooks, blankets, clothing, and ornaments.

With the annexation of New Zealand to the Crown in 1840 another stage of its economic development began. At that time the European population consisted roughly of missionaries, whalers and sealers, pakeha-Maoris and convicts escaped from Australia, traders and land-sharks. The last-mentioned were for the most part recent arrivals who, perceiving that annexation could not long be delayed, were inducing the Natives, often by most unscrupulous means, to part with their lands. But the Crown, in the Treaty of Waitangi, guaranteed the Maoris their land, and would recognize no transaction until satisfied of its equity. The colonists sent out by the New Zealand Company to settle in the Wellington, Wanganui, New Plymouth, and Nelson districts found their titles of land purchased from the company in England to be doubtful. The dispute with the Governor was not adjusted for years, and meanwhile the settlers became embroiled with the tribes acknowledging the headship of Te Rauparaha.

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* W. P. REEVES: *New Zealand*, pp. 31, 32; 1898.

The early Governors, with little revenue and no money to purchase land for settlement, were always in difficulties, the climax being reached when war with the Maoris of North Auckland broke out. Captain Grey (afterwards Sir George Grey) became Governor in November, 1845, and by his tact, energy, and ability soon obtained the respect and confidence of the natives and the majority of the Europeans. The war in the north was brought to a close, the land disputes were adjusted, and he, being furnished with money by the Colonial Office, was able to purchase from the natives large areas of unoccupied land, chiefly in the sparsely peopled South Island. Here were established, in 1848 and 1850 respectively, the Otago and Canterbury settlements, founded by associations working in conjunction with the New Zealand Company.

It is now easy to see that the company, which handed back its charter to the Crown in 1852, committed a grave error in not sending its first settlers to the east coast of the South Island. Wellington, with its central position and fine harbour, is undoubtedly the key of New Zealand, but at that time the district was occupied by warlike savages and largely covered with forest. On the other hand, most of Canterbury and Otago had no human occupants. Not only was the land well watered and fertile, it was for the most part treeless and admirably suited for rapid settlement. The sheepowners of Australia were quick to discover that conditions on the eastern side of the South Island were almost ideal for sheep. Progress, especially in Canterbury, was remarkable, and in a few years wool became the staple export of New Zealand. But it should be noted that the first export of wool was from Wellington, in 1846, and that even in 1853, when over 1,000,000 lb. weight were shipped, little came from Otago and none from Canterbury.

The other exports of the infant colony were chiefly native products, kauri timber, kauri-gum, and dressed flax. The gum was collected and the flax prepared by the Maoris, but the amounts were small and varied greatly from year to year. From the first colonization sawmills were established wherever kauri was readily accessible, and during this early period Europeans and Maoris grew rich by the timber trade. In the heyday of the Victorian goldfields, when so large a proportion of the population of Australia was engaged in gold-digging that insufficient foodstuffs were grown, wheat and flour were exported from New Zealand. This trade reached its maximum in 1856, when £68,000 worth was sent away, but shortly ceased. At that time very little of the South Island was under tillage, and the bulk of the grain was grown in the Auckland district.

Already, in the "fifties," Auckland and Christchurch had experienced fuel-scarcities, and a beginning had been made to mine coal at Whangarei, Motupipi, Malvern Hills, and Green Island. The gold discoveries of Victoria induced the Provincial Governments to offer rewards for its discovery in New Zealand, and small quantities were found near Coromandel in 1852, and larger amounts in the Collingwood district in 1857. Some copper was mined at Kawau Island, and a little copper and chrome from near Nelson.

It was not until 1861 that a really profitable goldfield was discovered, and the third stage in the economic development of the colony began. The rich finds of Otago attracted to New Zealand a large number of miners from Australia and other parts of the world. Scarcely had Otago reached its zenith as a gold-producer than equally rich discoveries began to be made

on the west coast of the Province of Canterbury. In 1867 gold-bearing quartz lodes were found in the North Island, where hitherto exploration had been retarded by the hostility of the Maoris. So rich in gold were some of these lodes that they attracted nearly as much attention as the readily worked alluvial patches of Otago and the West Coast. The hardships endured by the early prospectors in the icy rivers and bleak tussock-clad uplands of Otago were very great; and many men were drowned in the torrents of Westland or died of starvation and exposure in the dense dripping bush. Were it possible to assemble all the prospecting and mining costs of the gold won in New Zealand during the decade that began in 1861 these would be likely to be found to exceed the value of the gold, and this without placing any monetary value on the lives lost or the hardships endured. But the goldfields brought to New Zealand a large and vigorous population; settlement was incited and for a time guided by gold; and for many years a large population was maintained in comfort by alluvial mining. This was of immense benefit to agriculture, and induced the founding and stimulated the growth of other industries.

In the North Island, even before the discovery of gold in the South, the Government had purchased some millions of acres of land from the natives, sufficient to permit of real progress in settlement. But the disastrous Maori wars, which began in 1860 and continued desultorily for nearly ten years, left the colony with an unreproductive debt of several millions. For fifteen years after their close an expensive Armed Constabulary had to be maintained. Moreover, a sense of insecurity had been created, for farmers do not care to be made the mark of sudden raids. Millions of acres of Maori land had been confiscated, but some of this was given to friendly natives, and much more was ultimately handed back to the rebellious tribes. But in spite of the paralysis of settlement in the North Island and the low prices of pastoral products that had prevailed since 1865, the population of the colony had increased from the 75,000 it was when war began at Waitara in 1860 to more than three times that number in 1870; the revenue had increased in greater proportion, and the area of land in active use more than sevenfold. This growth of population and this progress of the colony was directly attributable to gold-mining.

In 1865 wheat and flour to the value of half a million were imported into the colony, but the low price obtained for pastoral products in that year and for several years after caused settlers in Canterbury and Otago to turn to wheat-growing, and to such good purpose that in 1867 a small surplus was available for export. This industry continued to expand rather irregularly till 1883, when £1,000,000 worth was exported. After that date, however, the development of railways in the United States allowed the wheat of the Middle West to reach Europe so cheaply that it no longer paid to grow wheat in New Zealand for that market. Oats also were largely grown during this period, and exported in moderate amount, chiefly to Australia.

Flax-dressing up till the Maori wars was entirely in the hands of the natives, but the quantity of fibre shipped was small, and tended to decrease. This trade reached a maximum as early as 1831, when 1,062 tons was exported, whereas in 1860 only 48 tons was sent from New Zealand. About the latter date, however, simple machines for dressing flax began to be devised, and some fibre so prepared was exported in 1866. There was quite

a boom in this industry in 1870, and good times continued till 1873; but after that the price of fibre on the London market fluctuated so violently that flax-dressing became largely speculative.

In 1870 Sir Julius Vogel initiated his public-works and immigration policy, by which money was borrowed by the Central Government on the London market in order that railways might be constructed, bridges built, and the means of communication throughout the colony generally improved. This may be taken to mark the beginning of the next stage in the economic history of New Zealand. During the early "seventies" prices for pastoral products were good, and this, together with the large amount of borrowed capital in circulation, brought about a land boom. This collapsed in 1878. The depression that followed was long-continued and severe; indeed, the colony did not fully recover till 1896. But during the preceding prosperous times many manufacturing industries and trading and transport businesses were established. The largest accumulations of capital were in Otago and Canterbury, hence the woollen-mills, the foundries, and the Union Company of the South.

Other industries made substantial progress. The wheat-growers required agricultural implements and twine as well as vehicles and harness, and, as their lands became exhausted, manures also; and industries meeting these demands were established. The increasing population needed clothing and food; and all kinds of wearing-apparel and footwear, condiments, confectionery, &c., began to be made. The sugar-refinery at Auckland was established in 1884, and sugar made from cane grown in Fiji began to displace that from Java and Mauritius. Buildings had to be provided; most were built of wood, but brick and cement were used in greater and greater amount. The manufacture of cement was undertaken at Mahurangi in 1886, and at Dunedin in the following year. In short, the tendency throughout this period of the colony's history was strongly towards self-reliance.

Coal, used in increased amount by the industries, railways, and steamships, was at first largely imported, but since 1878 the output from local mines has exceeded the imports, which tended to decrease, whereas the amount from New Zealand mines rapidly increased. But the output of gold diminished steadily. In 1871, when the Thames mines were at their zenith, it amounted to nearly £3,000,000; in 1890 it was rather more than a quarter of that sum. A little copper, manganese, and antimony ore was also exported during this period.

But the staple exports were pastoral products. In spite of the establishment of woollen-mills and the greatly increased population, the amount of export per head was maintained. Tallow, hides, and sheep-skins were sent away in large quantities, as well as rabbit-skins and leather. Meat-preserving works were established in Otago and Canterbury in 1870, and so long as beef and mutton were low in price their products, to the value of more that £100,000 per annum, were exported; but the increase in the number of home consumers greatly reduced this amount after 1875. The first frozen meat was sent away in 1882, since when the amount has rapidly increased. Dairy factories, which seem to have been established in the late "seventies," also began to export in notable amount in 1882. The fitting of refrigerating machinery to deep-sea ships, so that perishable products could be taken to distant markets, has changed the whole course of economic development in New Zealand.

(To be continued.)

CLATHRUS CIBARIUS, THE "BIRD-CAGE FUNGUS."

By G. H. CUNNINGHAM.

THIS fungus, known variously as "basket fungus," "lattice fungus," "Devil's purse," "*tutae whetu*," and "*tutae kehua*," belongs to the Phallaceae, a family included in the Basidiomycetes. It is found commonly throughout New Zealand during the late autumn and early spring, and appears to be partial to grassy places and freshly deposited earth on roadside cuttings; it is not confined to these localities, however, as it is frequently to be seen growing amongst decaying leaves on the forest-floor. It appears shortly after heavy rains.

The genus *Clathrus* occurs in Australasia, Ceylon, South America, the southern parts of North America, Africa, Europe, and in many of the tropical islands. In New Zealand it is represented by the subject of this paper.

CLATHRUS Micheli, *Nova Plant. Gen.*, p. 214, 1729.

Receptacle sessile, enclosed when immature in a three-layered volva, at maturity latticed, hollow, globose to obovate; arms of receptacle variously shaped, rough or smooth, tubular or cellular in structure. *Volva* at first obovate, at maturity cupulate with apex irregularly lacerate, consisting of three layers, exo-, meso-, and endo-peridium; the mesoperidium thick, gelatinous, and divided into a few large polygonal areas. *Gleba* lining inner surface of receptacle, gelatinous, coloured, fetid. *Spores* globose to elliptical, coloured.

Clathrus cibarius (Tul.) Ed. Fisch, *Sacc. Syll.*, vol. 7, p. 20, 1888.

Ileodictyon cibarium Tulasne, *Ann. Sci. Nat.*, p. 114, 1844.
Clathrus Tepperianus Ludw., *Bot. Centr.*, p. 5, 1890.
Ileodictyon giganteum Col., *Trans. N.Z. Inst.*, vol. 25, p. 324, 1892.

Receptacle sessile, white, subglobose or more commonly obovate, attaining a size of 15 cm. high, 10 cm. wide; composed of numerous obliquely anastomosing bars; bars smooth, or frequently pitted with numerous small, angular depressions; in section elliptical, tubular, or more frequently coarsely and irregularly cellular, 5–10 × 4–6 mm. diam., not or scarcely thickened at intersections (though in some forms attaining a thickness twice that of the bars). *Volva* dingy-white, obovate, with an irregularly lacerate apex, becoming at maturity cupulate, consisting of three layers —a thin tough white exoperidium, a thick (up to 7 mm.) gelatinous mesoperidium, and a delicate hyaline endoperidium—the two inner layers divided into several polygonal segments by cross-walls, corresponding with the arms of the receptacle. Attached to substratum by a few coarse, white, basal mycelial strands. *Gleba* covering inner surface of arms of receptacle, olivaceous, gelatinous, fetid. *Spores* embedded in gleba, olivaceous, elliptical, rounded at both ends, 6 × 4 μ.

Habitat.—Growing solitary or caespitose in open grassy places, newly formed roadside embankments, or amongst dead leaves on forest-floor.

Distribution.—Australia; Chile; common throughout lowland areas of New Zealand.

This species was originally described as an *Ileodictyon* by Tulasne, being placed by him in that genus because the arms of the receptacle were supposed to be tubular, whilst those of *Clathrus* were supposed to be coarsely cellular. This distinction does not hold with our species, however, as forms commonly occur which are obviously *C. cibarius*, yet possess cellular arms. As a rule the smaller forms have tubular arms, whilst the larger show the cellular structure.

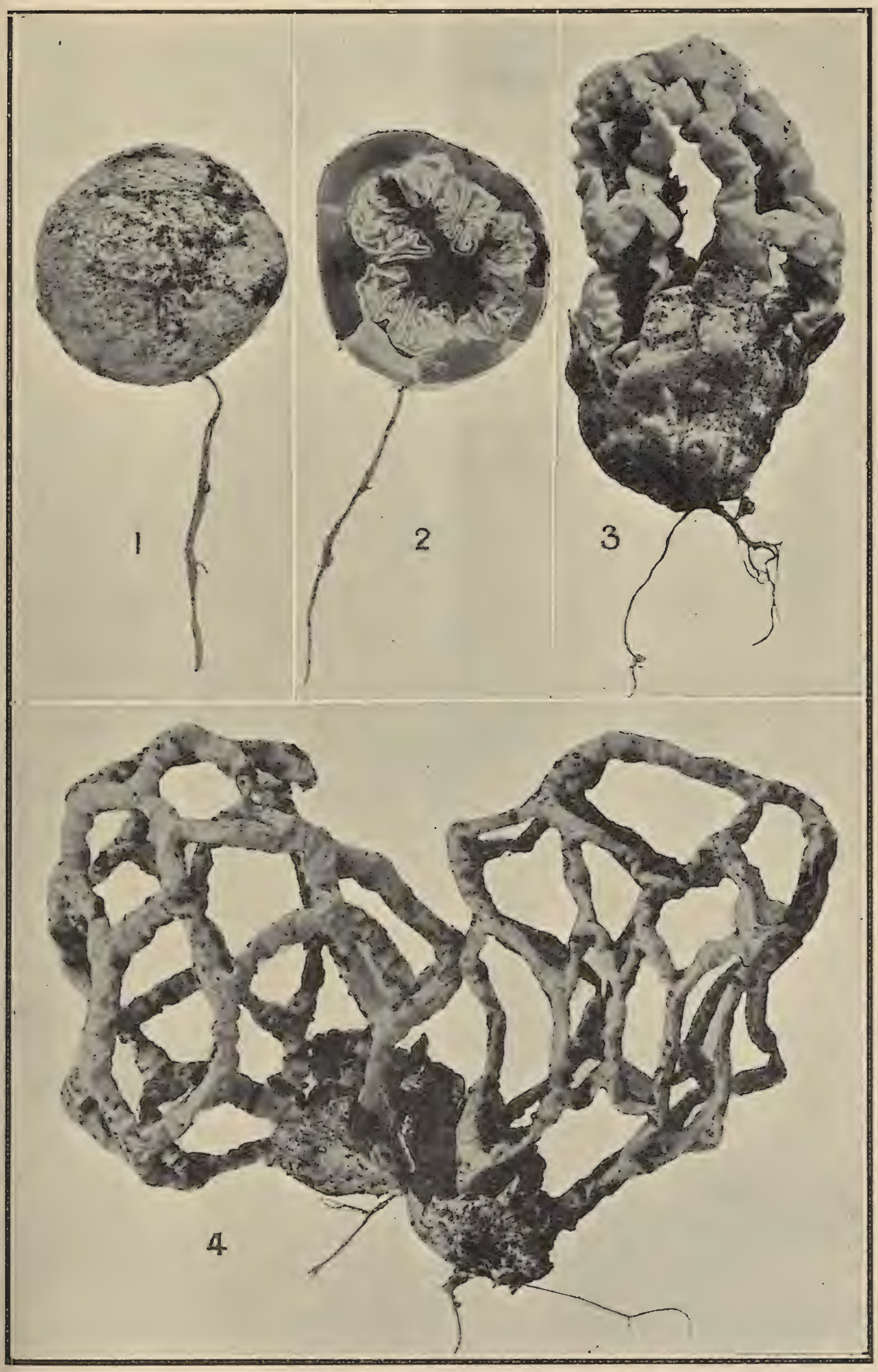
It is closely related to the Australian *C. gracilis* Schl., but differs chiefly in the larger elliptical arms and larger size of the receptacle.

LIFE-HISTORY.

From coarse mycelial strands which ramify in the substratum the volva, containing the receptacle, is developed. This at first is subterranean, but as it approaches maturity it comes to the surface of the ground, where it appears in the form of a dingy-white obovate "egg," which may attain a diameter of from 4 to 6 cm. The egg consists of two systems, the cortical and the medullary. The cortical system gives rise to the outer layer (exoperidium) of the volva, and to the receptacle. The medullary system gives rise to the gelatinous layer (mesoperidium) and the inner layer (endoperidium) of the volva, and to the gleba. When a median section is cut through the egg shortly before it reaches the surface it presents the appearance shown in fig. 2. The outer envelope of three layers is the volva, which is seen to be divided into several polygonal segments. Within the volva lies the receptacle, at this stage much convoluted, in turn enclosing the gleba, which consists of a brown cellular mass, completely filling the cavity enclosed within the receptacle. When examined under the microscope the gleba is seen to consist of a cellular structure formed of closely woven hyphal filaments. The inner walls of the cavities are lined with the hymenium, consisting of basidia and paraphyses arranged in columnar masses. The spores are sessile, six being borne on each basidium. At this stage the fungus does not possess the fetid odour characteristic of this species.

Prior to the rupture of the volva, the filaments, paraphyses, and basidia constituting the gleba gelatinize, the spores becoming embedded in the jelly-like matrix so formed. Owing to the pressure exerted by the developing receptacle, &c., the volva becomes ruptured at its apex, the suture following the septa of the irregular segments into which the volva is divided, and, the pressure being thus suddenly released, the receptacle rapidly expands, ultimately becoming several times as large as it was previous to the rupture of the volva. This rapid enlargement is due not to cell-division, but to the folds, into which the receptacle was thrown whilst within the volva, suddenly straightening out, so that in a mature plant the arms of the receptacle are quite smooth. The inner surface of the receptacle is at this stage lined with the gelatinous gleba in which the spores are embedded.

It now possesses a most fetid odour, resembling somewhat that of decaying fish, which serves to attract insects, particularly blow-flies. These appear to relish the fetid mass, as they frequently may be seen feeding on it. The deliquescence of the gleba, conspicuous nature of the receptacle, and fetid odour are devices on the part of the fungus to ensure insect-visitation and so secure dissemination of its spores, as it has been shown that the excreta of flies which have fed on the gleba contain enormous numbers of spores. Furthermore, experiments have shown that these



[*E. Bruce Levy. photos*

Clathrus cibarius (Tul.) Ed. Fisch.

FIG. 1.—Egg (natural size).
FIG. 2.—Egg. Section showing convoluted receptacle (natural size).
FIG. 3.—Plant two hours after rupture of volva (reduced one-half).
FIG. 4.—Mature plants (reduced one-half).

spores germinate readily (usually in about two months), and in fact appear to do so more readily than spores that have not passed through the alimentary tract of flies.

The receptacle in the mature plant is not attached to the volva, but merely partly contained within it, and is thus readily detached and carried by the wind some little distance from its place of origin. The appearance of these peculiar lattice-like structures without any visible means of attachment to the substratum have led to many curious conjectures as to their origin. To the Maori they were ever a source of wonderment and speculation. Forced to find some explanation of their (to him) mysterious appearance, and guided no doubt by their characteristic odour, he came to the conclusion that they were *tutae kehua* (literally, "faeces of ghosts") or *tutae whetu* ("faeces of the stars").

The specific name (*cibarius* = eatable) of our plant was applied to it from the belief that the fungus was used as an article of food by the Maori. Mr. Elsdon Best (to whom I am indebted for the names applied by the Maori to this species) informs me that to his knowledge it was not included among those fungi considered edible, and that, moreover, owing to its supposed supernatural origin, it is highly improbable it would be used in this manner.

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THE DEVELOPMENT AND FUTURE OF ELECTRIC MILKING IN NEW ZEALAND.

By LAURENCE BIRKS, B.Sc., M.Inst.C.E., &c.

FOLLOWING an article by the author on electric power for milking, in Volume 4 of the *Journal*, it is of interest to note the present position of this development, which promised and still promises to grow to such large dimensions, though naturally the drop in prices of agricultural products generally has delayed the extension. The returns show that there are already over eight hundred milking plants operated electrically in the Dominion from public electric supply systems in addition to those operated from private electrical installations, and the number is increasing rapidly.

In Canterbury electric power is yet generally available in only three farming districts, and the numbers of electrically operated milking plants in these districts are—Tai Tapu district, 36; Eyre County, 4; Rangiora County, 32; the charge being £21 per year per 3 h.p. motor.

The supply will be available this season in the Banks Peninsula, Ellesmere, and Kowai Electric-power Districts, and it is anticipated that the season will open with about fifty milking plants in each district. The charge in these districts will be £6 per horse-power per year, plus a unit charge of 3d. for the first 80 units per month, 2d. for the next 120 units per month, and 1½d. for all over 200 units per month.

In the Hawera Electric Supply Company's area there are fifty milking plants operated electrically. The charge is by meter at the rate of 4½d. per unit, less 10 per cent., and the consumption and annual cost for four typical milking plants for last season was as follows :—

Farm.	Number of Cows.	Total Units.	Annual Cost.
			£ s. d.
A	75	1,801	30 8 3
B	50	1,001	17 6 10
C	34	706	12 16 0
D	28	502	8 16 0

Monthly Demand (Units).

Farm.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.
A	159	252	148	212	242	188	192	250	132	26	..	..
B	90	144	100	115	120	104	115	141	72	..	..	..
C	63	73	108	69	123	90	96	84	..	..	..	..
D	51	81	51	69	81	57	57	75	..	..	..	..

These figures correspond fairly closely to those given in the previous article for the Canterbury examples—viz., 1,244, 922, 675, and 1,919 units per year—and the distribution over the year is practically the same. They work out at 0·38d. to 0·49d. per pound of butterfat.

The reduction of demand for the midwinter months is, of course, particularly advantageous to the electric supply authority in that it permits of the sale of the power elsewhere at the time when the demand for lighting and heating is the greatest, thus improving the load-factor.

In the Stratford Borough area eight plants are operated electrically, the charge being 4d. per unit, with a maximum of £15 per year.

The Murchison County has just installed a 100 h.p. automatic generating plant, using an old gold-mining water-race, and has run nine miles of reticulation, to which four milking plants are already connected.

In spite of the recent depression in butter-prices, the conversion of the milking plants in the Waikato district to electric drive is proceeding rapidly. The distribution in the farming districts of the power from the Government plant at Horahora Rapids is in the hands of four Electric-power Boards—viz., Thames, Te Awamutu, Central, and Cambridge. Supply was commenced in Thames and Cambridge districts early in 1921, but in Te Awamutu and Central it was practically into the opening of the milking season before supply was generally available, and as a result the conversion of the majority of the milking plants was postponed until the coming season. In spite

of this the proportion is very substantial, as set out in the following table :—

Number of Cows.	Thames.	Te Awamutu.	Central.	Cambridge.
Supply commenced	11/3/21	26/8/21	13/7/21	28/4/21
Number of milking plants in whole district	2,000	850	600	200
Number within reach of the mains	350	550	200	250
Number already converted or being converted to electric drive	350	137	160	86

The rates for energy in Thames Valley are £21 per year up to 7,000 lb. of butterfat produced, plus $\frac{1}{3}$d. per pound of butterfat in excess of 7,000 lb. This works out at about $\frac{3}{4}$d. per pound of butterfat for a herd of 35 cows producing 7,000 lb. of butterfat per year, and proportionately higher for a smaller herd and cheaper for a larger herd, down to 0·48d. per pound for a herd of 100 cows of good average yield. In the Te Awamutu district the rate is £6 per year per horse-power of connected load (usually 2 h.p.), plus a unit rate by meter of 3d. for the first 80 units per month, 2d. for the next 120 units per month, and 1$\frac{1}{2}$d. per unit for all over 200 units per month. In the Central and Cambridge districts the rates are practically the same.

In the Te Awamutu district the following are a few representative costs at the above rates :—

Number of Cows.	Horse-power.	Cost of Electricity for Year.
		£ s. d.
18	1	15 18 6
29	2	19 1 9
90	2	33 2 3
102	2	28 19 0

These include the highest and lowest charges in this district, the balance ranging between £20 and £30. They range in cost per pound of butterfat from $\frac{1}{3}$d. in the large herds up to 1d. in the smallest herd.

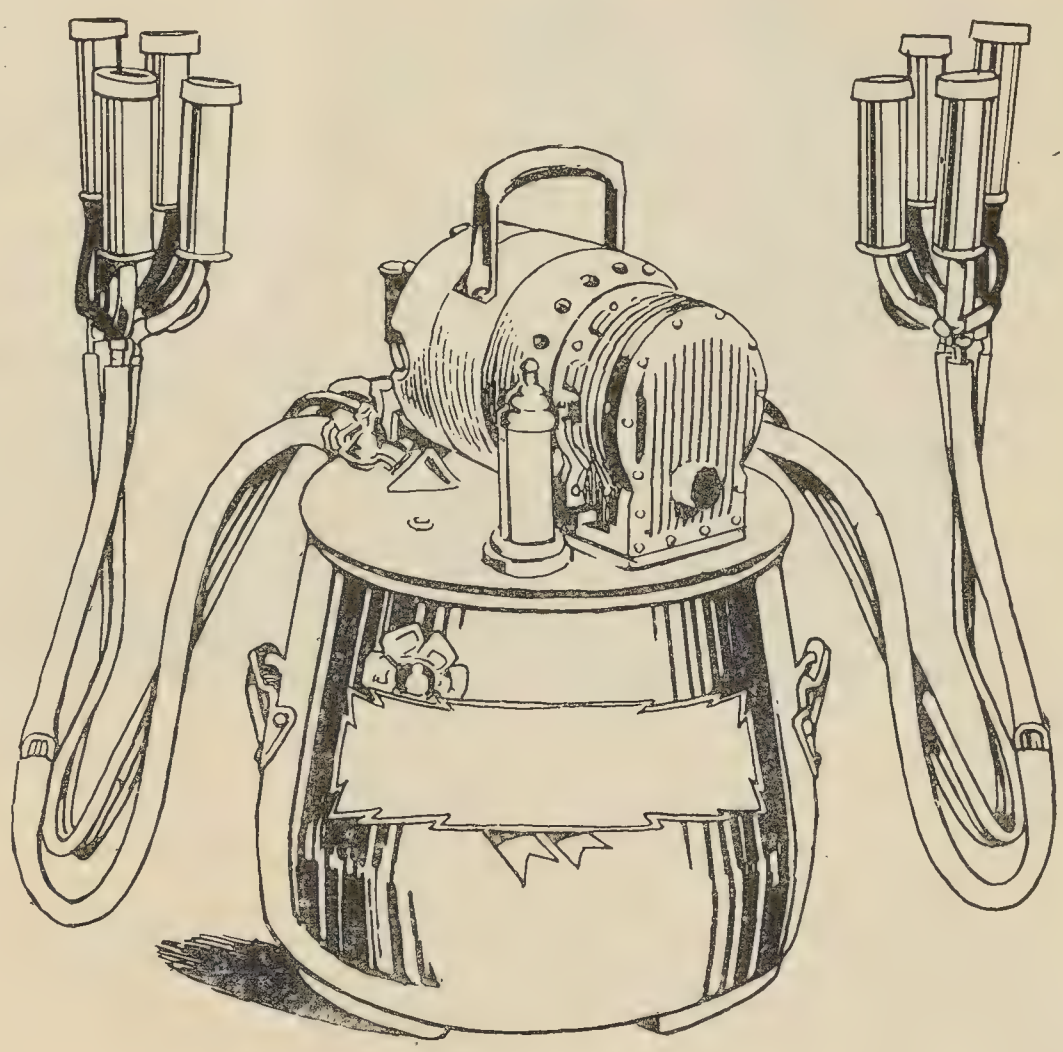
The competing source of power for milking purposes is benzine at £1 1s. to £1 10s. per case, according to the distance of cartage from the railway-station, the consumption usually ranging from twenty to fifty cases per year. The electric power thus has no difficulty in competing on the score of cost of fuel alone apart from the lower cost of maintenance, lower first cost, and the great advantages of reliability, simplicity, and ease of operation of the electric motor as compared with the oil-engine.

The number of electrically operated milking plants is much less than it would otherwise have been owing to the drop in the price of butterfat, rendering the financing difficult to many dairy-farmers. The Thames Valley Board had met this position from the start by financing the farmers and undertaking the work of installing the electrical system, and hence the large proportion in its district. The Te Awamutu and the other Boards are now making arrangements to advance the cost of the installation on time payments, and as a result the proportion of electrically operated milking plants in these districts will probably be as large next season as in the Thames Valley.

As a further method of cheapening the cost of installation the Boards are arranging, where practicable, to call comprehensive tenders for the whole of the wiring and installation of motor for groups of farms up to fifteen within a given district simultaneously. As a result of the arrangement, applications for electric supply are being received so fast in some districts that it is difficult to deal with them all. Moreover, owing to the saving in transport expenses on the part of the wiring contractors, the cost of the installation is materially reduced by this grouping of the work of installation.

In addition to these districts in which the supply is already available, the reticulation is being erected in several other districts, particularly in the Southland, Manawatu, Rangitikei, Horowhenua, Wairarapa, Opunake, and Kaponga districts, where the necessary plant is being installed, which will involve a large increase in the number of electric milking plants in operation within a couple of years.

The history of the development of electric-power milking has been the replacement of the standard 3 h.p. oil-engine driving the ordinary releaser milking-machines by, first, a 3 h.p. electric motor. This was found to be largely in excess of the power actually required, and that even 1 h.p. will operate sufficient milking-machines at once to deal with a herd of a hundred cows. But a large proportion of the herds range from ten to twenty cows, and for a herd of this size a plant capable of milking two cows at a time is all that is required. A machine is now available of a much more compact type, capable of fulfilling this service, and driven by a motor of only $\frac{1}{4}$ h.p. Moreover, it has the great advantage that the motor vacuum-pump and releaser are all mounted direct on the lid of the bucket, and the whole outfit is thus exceedingly portable, and can be carried about in one hand, thus reducing the cost of the building and accessory equipment required in connection with it to a minimum. The complete apparatus is shown in the figure herewith. The cost of operation will also be much less than the standard 1 h.p. or 2 h.p. plants, though, of course, with the self-contained plant the separator and water-supply pump, if required, cannot be driven from the same shaft as is usual with the larger installations, and separate motors have to be installed for this purpose. The Thames Valley Power Board have fixed a charge ranging from £7 per year upwards for the energy for this $\frac{1}{4}$ h.p. outfit. Though it will probably not take the place of the standard arrangement for large herds of thirty to one hundred head, the $\frac{1}{4}$ h.p. unit will probably have a large influence in extending the demand for electric power for milking the smaller herds of the Dominion.



PASTIMES OF MAORI CHILDREN.

By ELSDON BEST, Dominion Museum.

With illustrations by J. MCDONALD.

UPOKOTITI.

THE illustration shows the first action in this childish pastime, as described in Volume 34 of the *Transactions of the New Zealand Institute*, page 52. In a paper, "Games, Sports, and Amusements of the Northern Queensland Aboriginals," by Walter E. Roth, B.A., M.R.C.S., published twenty years ago,* was given an illustration showing native children of that region performing the same action, their hands in the same position. It was to illustrate a native pastime.

The Maori Game of *Upokotiti.*

HAPI TAWA.

This picture illustrates the second act in the pastime of *hapi tawa,* in which children dart their fingers into the cupped hands of one who strives to catch the swiftly moving hands.

The Maori Game of *Hapi Tawa.*

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* Report of the Australasian Association for the Advancement of Science, Hobart, 1902, page 493.

MAORI GAMES AND PASTIMES.

Stilt-walking.

By ELSDON BEST, Dominion Museum.

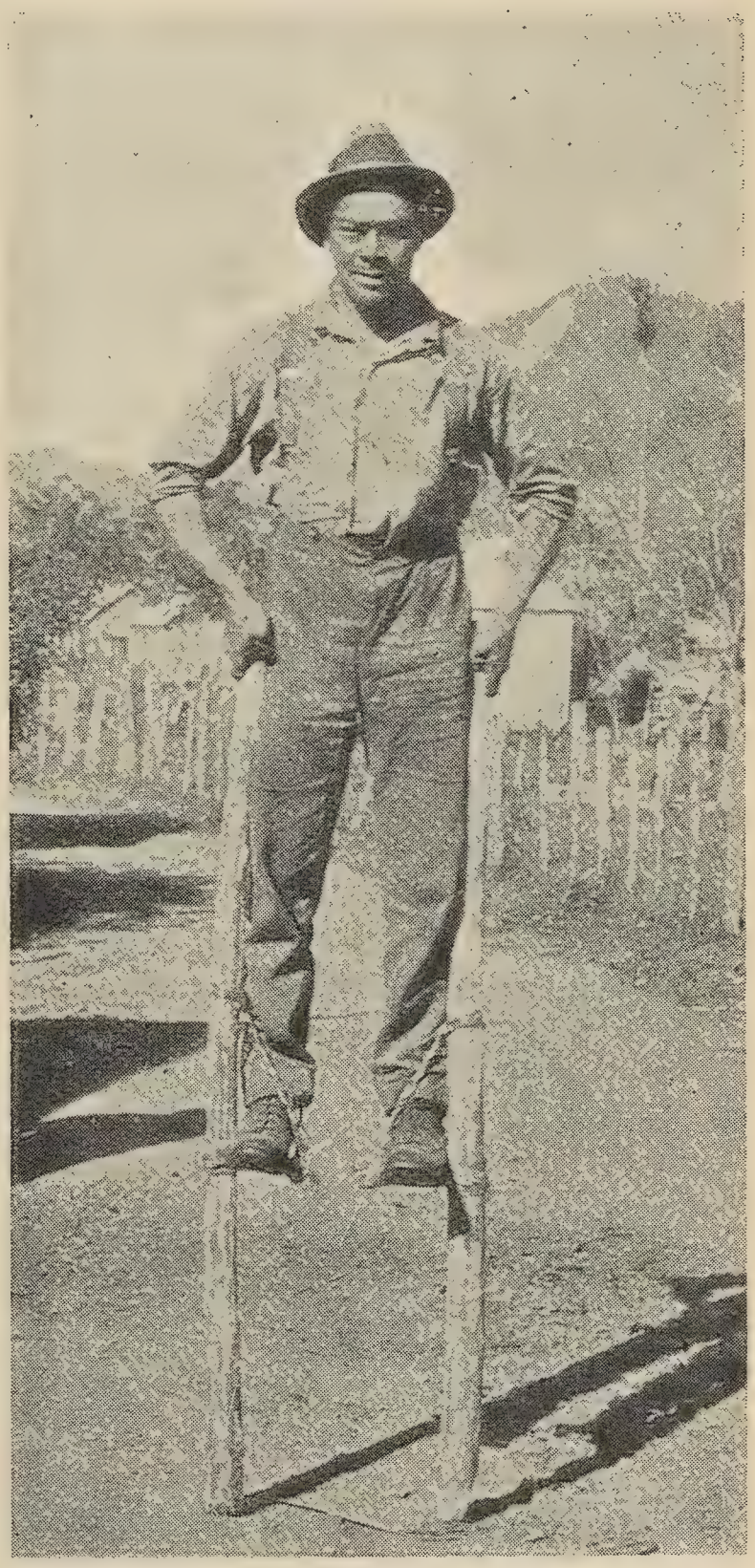
Illustration by J. MCDONALD.

STILT-WALKING was a favoured diversion of Maori youths in pre-European days. The illustration shows Apirana Tukairangi, of Taupo, late of Gallipoli and the western front, disporting himself in the peaceful hamlet of Koriniti, on the Whanganui.

There are a number of native names for stilts, including *pou turu*, *pou toti*, *pou koki*, *pou toko*, *pou tokorangi*, and *matakapua*. In some cases the foot-rests were attached as shown in the illustration, in others the base of a branch was utilized for the purpose. In former times young folk indulged in stilt races, and in crossing streams and rivers on stilts. Another form was wrestling on stilts, in which the bouts must have been of short duration.

In some cases the stilts were detachable ones, resembling those of the *ko* or old native spade. So far as we are aware these attachments never equalled those made by the Marquesans, who adorned them with elaborate carved designs.

Stilts are occasionally referred to in Maori tradition, as in the story of Tama stealing the breadfruit of Uenuku, in far-off Polynesia. A carved representation of Tama on stilts is to be seen in the tribal meeting-house, Tama-te-Kapua, at Ohinemutu, Rotorua, and also in the large house belonging to the Arawa chief, Mita Taupopoki, of Whakarewarewa.



LIFE-HISTORY OF SIPHANTA ACUTA (WALK.), THE LARGE GREEN PLANT-HOPPER.

By J. G. MYERS, F.E.S., Biology Laboratory, Department of Agriculture.

INTRODUCTION.

THE large green plant-hopper—*Siphanta acuta* (Walk.)—known in Hawaii, from its jumping-powers, as the "torpedo-bug," is probably, next to the cicadas, the most conspicuous homopterous insect in the Dominion. In this country it has not been studied, while elsewhere very little information has been recorded concerning its life-history and habits. Kirkaldy (1908, p. 161) mentions having partially studied the metamorphoses, and he gives a very clear drawing of the final nymphal instar, with a somewhat obscure one of the ova *in situ* (1907, pl. vi, figs. 17–20). Froggatt (*Australian Insects*, p. 359, no date) says that "its pale-green fluffy larvae feed upon the sap of many plants, and readily jump when touched."

ORIGIN AND DISTRIBUTION.

Siphanta acuta is one of the commonest fulgoroid Homoptera of New South Wales, and is found also in Queensland and Tasmania (Melichar). It has been introduced into Hawaii, where it feeds on guava, on *Acacia koa* and other trees, and on the coffee-plant, on which last it has become a pest of considerable importance. It was first recorded from New Zealand by Kirkaldy (1909, p. 81), who received specimens from Auckland. He suggested that it was probably introduced from Australia with the ornamental shrubs on which it feeds. The two centres of greatest abundance in this country are Nelson and Auckland, in both of which districts it is sometimes very common. It occurs at least as far north as Whangarei, and probably farther. In the more southerly portions of the North Island it is a rare insect.

SYNONYMY AND CLASSIFICATION.

Siphanta acuta was first described by Walker in 1850 from "New Holland," as a species of *Poeciloptera*. Kirkaldy in 1899 treated it as a new species, and erected for its reception a new genus, *Phalainesthes*. In 1902 it was correctly placed by Melichar in Stål's genus *Siphanta*. The synonymy therefore stands briefly as follows:—

Poeciloptera acuta Walk. 1850.
Phalainesthes schauinslandi Kirkaldy. 1899.
Siphanta acuta Melichar. 1902.

The genus *Siphanta* occurs throughout Australia, Tasmania, Java, St. Helena, and the Hawaiian Isles (introduced). It is placed in the family Flatidae, which consists of large-winged, often brightly coloured, moth-like forms, of which the introduced fireblight plant-hopper (*Sephena cinerea* Kirk.) is the only other representative in New Zealand. The Flatidae form one of the fourteen families into which the Fulgoroidea, a superfamily of the Auchenorrhynchous Homoptera, is divided.

LIFE-HISTORY.

The Egg.

Eggs have been found from December to February inclusive, and as late as the 25th May, but absence from the area where these plant-hoppers are numerous has prevented the record of definite dates. Eggs have been received at this laboratory during the above period, but the egg season may overlap at both ends. The eggs which were finally hatched and successfully reared were sent for identification by Mr. T. S. Skeates, of Auckland, all previous attempts at rearing having failed through ignorance of the exact conditions required. Once experience dictated the correct technique, further progress was much facilitated.

The eggs were found plentifully by the writer at Whangarei, glued to the leaves of lemons and of poor-man oranges. Each patch of eggs is roughly circular, with an average diameter of 6 millimetres and a greatest thickness of 1 millimetre, thinning at the sides to grade imperceptibly into the surface of the leaf. The eggs are packed fairly regularly, those nearer the centre being inclined more nearly to the vertical than those on the periphery, so that the whole egg-cushion is flatly dome-shaped. For about a sixth part of the circumference the sloping sides of the six or seven ova of the apparently last deposited row are fully visible. On the rest of the surface the mere tips of the eggs are seen embedded in the dark, semi-transparent material which glues them all into a solid cake, and fastens that cake to the leaf. The whole mass is surrounded by a thin, irregular edging of this adhesive substance, thus merging the outline of the dome into the surface of the leaf. The adhesive material projects in a reticulated pattern between the eggs, in places standing out as solid knobs and bumps. An examination of the underside of the egg-cushion shows that on five-sixths or so of the periphery, as indicated above, eighteen to twenty ova are arranged with their long axes parallel to the leaf-surface and their inner ends pointing towards the remaining sixth portion of the circumference, where the sloping row of seven to eight eggs evidently represents the last eggs laid. The centre of the under-surface of the mass consists of the very closely packed butts of those eggs which stand inclined nearer to the vertical though considerably far from it. Each egg-cushion contains approximately 90 to 110 eggs, the average length of each ovum being 1·2 millimetres.

First Instar.

The young, for some time after hatching, remain in a close group, squatting on and around the empty egg-cushion, which retains all its shape, though frequently a black fungus grows on the empty cases. These very young nymphs are, however, ready to hop with astonishing vigour at the smallest stimulus. Owing to the fact that the eggs of the brood which was eventually the only one reared with any success hatched in company with very young nymphs of uncertain age, in transit, it was not possible to isolate the first instar with absolute certainty. There is thus a very faint possibility that the instar described here is the second, our second the third, and so on; but the writer has every reason to believe, apart from absolute proof, that *all* the young nymphs isolated at the commencement of the rearing were really in their first stadium.

First instar (possibly second): Vertex elongate, tumescent. Pronotum laterally keeled, with indications of a longitudinal median keel which

continues down the mesonotum and metanotum. Mesonotum with a subparallel ridge on each side of disc. Segmentation of abdomen very pronounced; that of thorax indistinct dorsally. A bunch of white, waxy filaments on each side of sixth visible abdominal tergite, and a much longer tuft on each side of the extremity of the last apparent tergite, on each side of the anal segment. These filaments vary tremendously in length in different individuals (see below for a discussion of the use of these characteristic fulgorid appendages). Rostrum reaching almost to hind coxae. Frons elliptico-ovoid with a faint median longitudinal ridge. Colour very pale greenish-white, appendages transparent. Whole surface covered with fine white mealy powder, especially on the sides. The second and third visible abdominal terga with a triangular red spot at the middle of the cephalad border. A small roundish black spot at the caudal extremity of the lateral ridge on the disc of mesonotum—*i.e.*, on hind-border of mesonotum.

Length just before ecdysis, exclusive of caudal filaments, 2·4 mm.

Second Instar.

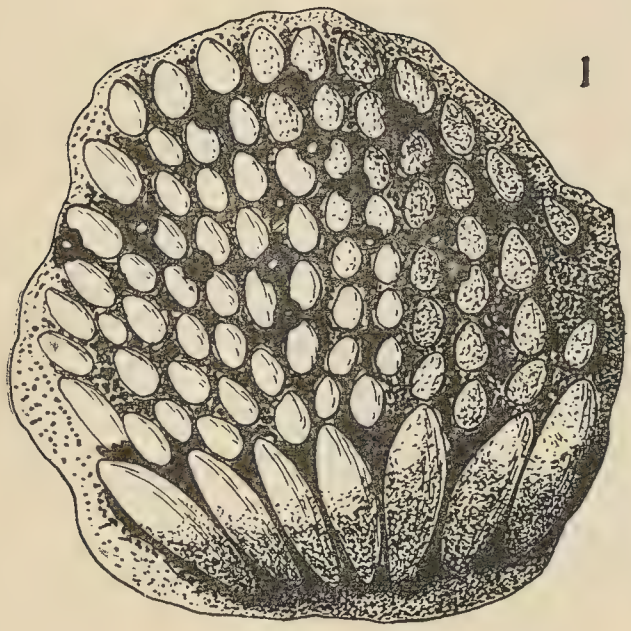
Head less produced, and slightly more tumescent. Median ridge of pronotum more distinct; disc having a tuberculate appearance owing to the number of specialized sensory organs. The apparent last abdominal segment very truncate but with a stronger growth of silky filaments. Rostrum reaching to and sometimes slightly beyond last coxae. Colour slightly more greenish. In addition to the spots in the first instar there is a black diffuse spot on each side of the disc of mesonotum lateral to the spots described above. There is a large and conspicuous oblong black spot almost at the apex of each posterior angle of the metanotum. Second joint of antenna more globose and larger in proportion.

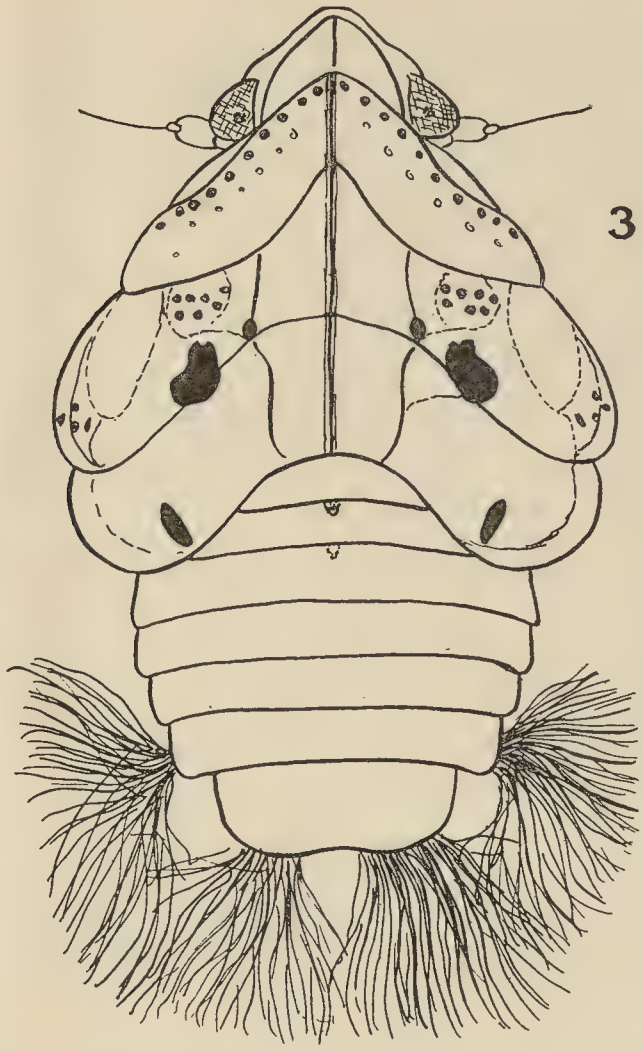
Length, exclusive of caudal filaments, 3 mm.

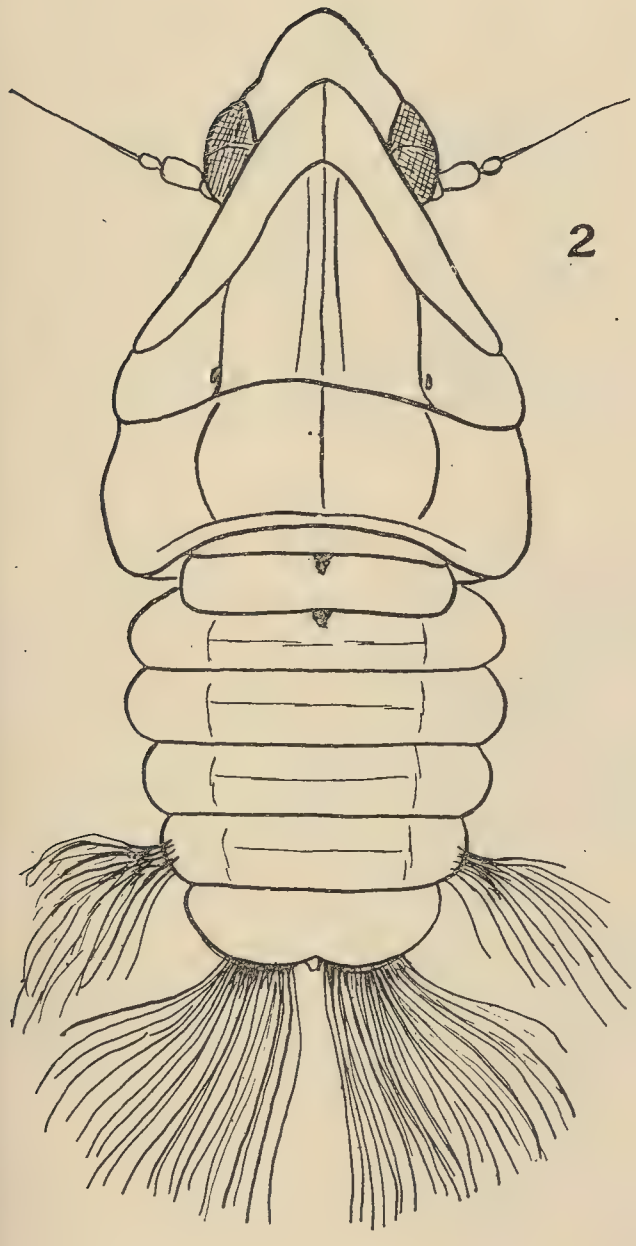
Third Instar.

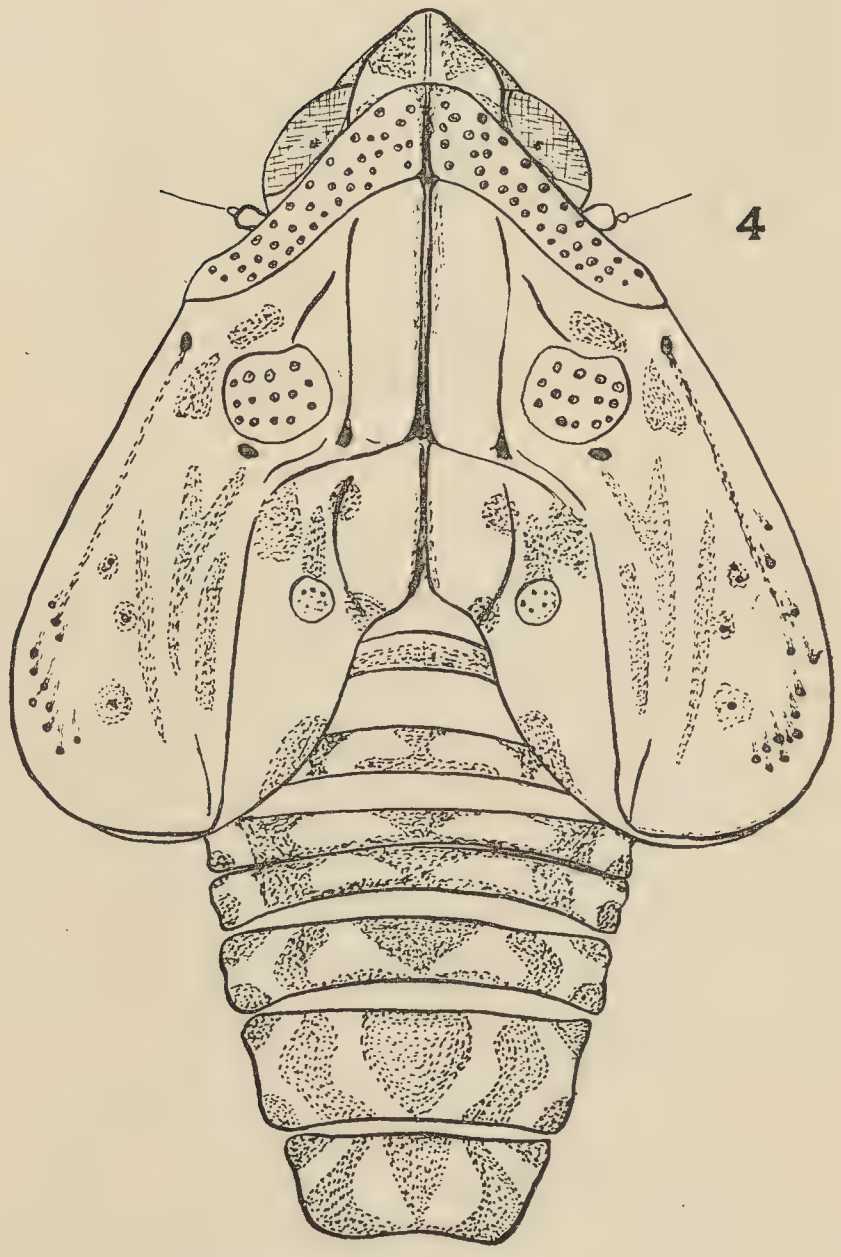
Whole insect much wider in proportion. Head not tumescent. Vertex flat, bordered by a keel, and bearing a median longitudinal keel. Second joint of antenna very much larger in proportion and swollen. Pronotum with the lateral keels very pronounced, meeting in front and diverging caudad, bordered by two parallel rows of the prominent cup-like sense-organs, about ten in front row and six in rear row on each side. Nota with a conspicuous median longitudinal bright-yellow ridge. A raised boss-like area on each side of disc of mesonotum has about six of the above-described sensory organs arranged in two rows. About eleven similar organs occur on the flat lateral expansions of the mesonotum. Colour pale green with less pruinosity than in the younger instars. Median streak of thorax bright yellow. Eyes whitish-transparent, with a black spot showing through. The six black spots of the second instar are present, much intensified and enlarged, especially the diffuse spots on the disc of mesonotum, which are now large, very clearly defined black blotches, like splashes of Indian ink; and in addition there is a clear black spot on each side of the anterior portion of mesonotum. The red spot on the second apparent abdominal tergum is intensified and very distinct; that on the third is, however, almost obsolete. The caudal filaments are tangled and very silky.

Length, excluding filaments, 3·6 mm.









Siphanta acuta.

FIG. 1.—Egg-cushion : dorsal view. × 7.
FIG. 2.—First instar nymph. × 28.
FIG. 3.—Third instar nymph. × 16.
FIG. 4.—Fifth instar. × 17. Caudal filaments omitted. Stippled areas red.

Fourth Instar.

Differs chiefly in colour from the preceding, but the following structural characters are either emphasized or different. Vertex depressed, with the thickened fore-border forming a rim. Prominences of pronotum (special sensory organs—Kirkaldy) very distinct. Pronotum sides almost parallel for some distance, but diverging finally caudad; a strong central longitudinal ridge. Mesonotum with the lateral granulated sensory area on each side sharply defined like a rounded superposed plaque; about a dozen sensory cups on each plaque; a prominent median longitudinal ridge; a longitudinal ridge on each side ending in distinct black spot and separating the granulated plaque on each side from the central ridge. Tegmen-sheaths reaching farther caudad and distinctly overlapping the wing-sheaths. Filaments as in preceding instar. Rostrum reaching slightly beyond hind coxae. Colour yellowish-green marked with red. Vertex with a large pinkish red spot on each side of disc; posterior portion of raised lateral border also reddish. Frons with a row of pinkish granulations down each side. Pronotum with the sensory organs ringed with red; the central ridge yellowish, except cephalad, where it is reddish. Mesonotum with the sensory cups, a few smudges on the tegmen-sheaths, and the cephalad terminations of the three discal longitudinal ridges reddish; a large jet-black spot on the posterior border immediately caudad of each granulated plaque, and a black dot at the caudal end of each discal lateral ridge; disc of mesonotum, between the two plaques, strongly suffused with canary-yellow. Metanotum tinged with yellowish; a curved ridge on each side of disc, two large diffuse spots lateral to this ridge on each side, and a small portion of the posterior border reddish; a jet-black spot on the inner posterior border of each wing-pad. Abdomen pale-greenish; a median longitudinal band, a small and a larger lateral splash, and most of the posterior margin of each segment red. Legs pinkish, the distal spines of hind tibia and hind basitarsus tipped with fuscous passing into black.

Length, excluding filaments, 4 mm.

This instar undergoes a gradual but very striking change about half-way through the stadium, before ecdysis into next instar. The red markings, though still visible under magnification as distinct areas, fade to an even paler (less yellowish) green than the rest of the body, so that to the naked eye the insect changes from red to pale green. The only red spots left are those primary ones (mere inconspicuous specks) possessed also by the previous instar. All the red which belongs peculiarly to the present instar is lost. This change is very gradual, taking about a fort-night under laboratory conditions (in one instance thirteen days). At the same time the abdomen elongates considerably, becoming frequently as long as head and nota together. This elongation occurs in all instars prior to ecdysis.

Fifth Instar.

Vertex shovel-shaped, depressed, with a raised rim. Pronotum with the sensory cups pinkish with black centres; central longitudinal ridge very distinct. Longitudinal ridge of mesonotum also very distinct; two curved lateral ridges lined with pink and followed by the round plaques containing apparently about fourteen sensory cups. Metanotum with a similar central longitudinal ridge, and a lateral one on each side followed by a red, slightly raised disc. The seven unmodified dorsal sclerites of

abdomen are apt to be separated by a space of intersegmental membrane, rather narrower than the sclerites themselves. Rostrum reaching slightly beyond hind coxae. Colour in the main reddish, owing to the large number of crowded pinkish markings, arranged as follows: Ground-colour greenish-white. Vertex with a pinkish spot on each side. Pronotum suffused with pink, especially fore-border. Tegminal pads with numerous longitudinal red stripes often terminating in distinct black dots as shown in the figure. Every dorsal sclerite of abdomen has a median triangular reddish patch with apex caudad, and a curved longitudinal band running from fore to hind border on each side. Segmental margins tend to be reddish. Two obscurely outlined reddish spots on the extreme edge of each tergite. Eyes greenish. Antennae pale-pinkish, flagella tipped with fuscous. Ventrally very pale greenish, except the frons, which is edged with reddish; the legs, which are suffused and edged with pink (spines black); and the tegmen and wing-pads, which project like a carapace and are thus visible from beneath. Caudal filaments shorter in proportion than in previous instars, and shining with a slight golden tinge. The lateral filaments of abdomen are small tufts.

Length, exclusive of filaments, 5 mm. Greatest width, 3·75 mm.

For some days (usually about three) after ecdysis the fifth instar is greenish without any tinge of red. The black spots of the nota and alar pads, and to a less extent the sensory cups of the pronotum, are alone conspicuous. Some of the more distinct red stripes of the fully coloured nymph are represented by pale-yellowish on the green ground-colour, while the median ridge of the nota is also yellowish, but still quite faint. The red colour is gained very slowly, the nymph being fully pink on about the fifth day after ecdysis, but not acquiring the maximum intensity of redness until the seventh or eighth day. Thereafter a very gradual further change takes place, once more to green—a green uniform and more vivid than that immediately after ecdysis. At the same time the abdomen lengthens and appears swollen, as the fifth instar nymph prepares for the final ecdysis.

Imago.

As there are no other species of the genus *Siphanta* in New Zealand so far recorded, the large green plant-hopper can be easily distinguished by its size (1 in. wing-expanse), very vivid green colour, triangular, broadly truncate tegmina or forewings, pink eyes, and pointed head. In repose the tegmina completely cover the body like the sides of a sloping roof. It would needlessly increase the length of this paper to give a full technical description of the imago.

Ecdysis.

A close examination of the process of ecdysis, or casting of the skin, is rewarded by the discovery of several peculiar features. As the time for ecdysis approaches the nymph's abdomen elongates and appears somewhat swollen, while in the fourth and fifth instars the colour changes from red to green. In the fifth instar also the alar pads become somewhat separated, partially exposing the hindwing pads beneath those of the tegmina. The insect becomes sluggish, leaves the stem which is its constant feeding-place and clings tenaciously to a leaf, usually the under-surface. From this position it refuses to stir at any stimulus whatever, evincing, indeed, when forced, considerable difficulty in loosening its hold. The actual emergence, for which these preparations take some time, occurs usually at night or early morning. The rupture of the old cuticle takes

place along the mid-dorsal line from the posterior of the metanotum cephalad to the frons, which is left intact, although the transverse split extends along each side of it between frons and eyes, to about half-way along the latter. The imprisoned nymph (or imago, as the case may be) appears and gradually disengages head and thorax. The motive force is not, however, apparent. There is much swelling and contracting alternately, each swell pushing back an almost infinitesimal portion of the slough, and it appears that these movements of the abdomen—which, as we have seen, swells and elongates before the commencement of ecdysis —are probably the sole force in extricating the nymph from the exuviae. It is almost analogous to the case of the Diptera; but here we have a whole abdomen acting the part of a ptilinum. The very tip of the abdomen is disengaged before the last claws are free, and the legs are packed fairly closely out of the way, beneath the body. In the case of the emergence of a fifth from a fourth instar, the newly-emerged fifth instar is a shining green, with no trace of the future pruinosity, and with a swollen, parallel-sided abdomen, longer, if anything, than the head and nota together. The points and spots which will eventually be red are visible at this early stage as paler areas, which seem to differ structurally —in fact, they appear possibly to represent points of muscle attachment to the exoskeleton. The abdomen commences to shrink almost immediately, and later is a very inconspicuous portion of the body. Filaments begin to appear about two hours after ecdysis, both caudally and laterally, but most conspicuously on the apparent penultimate segment.

Summary of Life-history.

The shortest period under autumn and winter laboratory conditions from egg to imago was eighty-five days, but I am satisfied that the conditions are so unnatural that this gives no criterion whatever of the length of the life-cycle in nature. These specimens were reared late in the season, on a strange food-plant, four hundred miles south of the region where the eggs were laid. The points of interest in this life-history are the intrastadial colour changes of the fourth and fifth instars (in the latter case a double change), and the method of extrication from the exuviae at ecdysis.

HABITS.

Although the younger instars frequently feed on the leaves the older instars invariably prefer the stem. Third, fourth, and fifth instars, when the spray of food plant is kept vertical, invariably keep an upright position on the stem itself, with their long axis parallel to that of the branch. They are very inactive, sitting for hours with their beaks applied to the stem. Occasionally an abdomen commences to vibrate — the vibrations pass gradually into an up-and-down thrashing—and at the moment of greatest amplitude of the movement, on the summit of an up-stroke, a perfectly spherical bead of honeydew, almost as big as the width of the abdomen at its tip, is exuded, and rapidly jerked away between the tufts of filaments which lie on each side of the anal extremity, and which are parted for the purpose. The younger instars are less forcible in this process, and frequently show a bead of honeydew held by the caudal filaments long after it has left the body. The honeydew is a dark bluish-green, sweetish, transparent liquid, which speedily grows a black fungus if allowed to accumulate on the floor of the breeding-vessel. Its colour may be due to a similar peculiarity in the sap of the food plant (in this case *Coprosma retusa*).

All the nymphs have a peculiar habit of swaying rhythmically from side to side—either when stationary or during the act of walking slowly. This movement, which swings the whole body clear of the surface, has been noted also in aradid nymphs, and is quite distinct from the abdominal wavings which accompany the ejection of honeydew.

The fifth instar nymphs can jump as far as 2 ft. The adult plant-hopper, if it jumps at all, almost always spreads its wings while in the air.

The older nymphs are often surrounded by a mealy halo of white pruinose material from the filaments, which are easily detachable. The formation of such circles, between which and the body itself of the insect is always a clear space, would be best explained by the supposition that the nymphs move round frequently without changing to a like extent the position of the rostrum. As mentioned above, the filaments are easily detachable, and yet I have seen a nymph carrying for as long as a day the recently cast skin entangled in these waxy tufts. This white waxy material forming the filaments is widespread throughout the Homoptera, but especially in Coccidae and Fulgoroidea. The filaments, if accidentally rubbed off, are soon replaced. Their function is problematical. It has been suggested that the mealy matter is protective. In other genera masses of it are used to envelop the eggs on deposition, while a species of *Myndus* in North America, according to Osborn, in the nymphal stadia lives below ground in crevices lined by the filamentous material from the abdominal tufts (Swezey).

The favourite food of this species in the north of this Island seems to be citrus-trees of various kinds, while in Nelson the ornamental shrubs of the gardens are favoured.

ENEMIES.

The eggs are parasitized in Hawaii by a minute hymenopteron, *Aphanomerus pusillus*. This egg-parasite, or a closely allied one, was emerging in large numbers from ova at Whangarei on the 25th May, when unhatched eggs, a very few nymphs of all ages, and one or two adult plant-hoppers were also observed. The steel-blue ladybird (*Orcus chalybeus*), which so efficiently keeps the northern citrus-orchards free from scale, devours the egg cushions wholesale—at least, when placed in contact with them in the orchard.

TECHNIQUE.

The nymphs were found to thrive in *closed* Petri dishes or large, wide tubes, in which the food plant finally selected on account of its succulence —*Coprosma retusa*—kept fresh for a week or more. When necessary the hoppers could be picked up, isolated, or transferred with a camel's-hair brush, from the point of which they apparently found it impossible to leap.

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DISCOVERY OF GRAPTOLITES AT CAPE PROVIDENCE, SOUTHLAND.

By Professor JAMES PARK, F.G.S., Otago University School of Mines, Dunedin.

DURING a recent visit to the South-west Sounds I discovered a bed of black slaty shale at Cape Providence, Chalky Sound, containing a large assemblage of well-preserved graptolites. The shales, which were tilted at high angles, are flaggy and much jointed. Their general strike, as observed along the west side of Chalky Inlet, is to the east of north, with a high dip to the west. Nests of graphitic matter are plentiful along the bedding-planes of the shales, and oval disc-like markings that may be the impressions of chitinous organisms are commonly associated with the graptolites. Most of the fossils lie within a zone less than 1 ft. thick.

The species seem to be almost identical with those described by Dr. Ethel M. R. Shakespear* from Golden Ridge, Collingwood. They include —*Bryograptus Lapworthi* Ruedemann, *Dichograptus octobrachiatus* Hall, *Didymograptus extensus* Hall, *D. gibberculus* Nicholson, *D. nitidus* Hall, *D. nanus* Lapworth, *Clonograptus tenellus* (Linnarsson), *Loganagraptus Logani* Hall, *Phyllograptus Anna* Hall, *P. typus* Hall, *P. angustifolius* Hall, *Tetragraptus Amii* Elles and Wood, *T. Bigsbyi* Hall, *T. quadribrachiatus* Hall, *T. serra* (Brongniart).

These species, with one exception, would indicate an age somewhere about Middle Skiddavian. In Europe *Clonograptus tenellus* is a Tremadocian form. At Cape Providence it occurs on the same slab as *Didymograptus nanus*.

The graptolites collected by Mr. A. McKay, F.G.S., in 1898, at the Morning Star Mine, Preservation Inlet, according to European standards, are Upper Cambrian.† At the Morning Star the rocks are slaty shales and mica-schist. Half-way between Preservation Inlet and Cape Providence the rocks are slaty shales and greywackes, both slightly altered. They strike north-north-east and south-south-west, and dip west at angles of about 80°.

The distance from the Morning Star to Cape Providence is about fourteen miles. As it is impossible to believe that the two graptolite horizons are separated by the great thickness of strata that the distance and dip would seem to indicate, I conclude that the ancient Palaeozoic strata in the South-west Sounds occur in a series of sharp truncated folds that all incline to the west.

In 1921‡ I showed that the great succession of (*a*) gneisses, (*b*) crystalline schists and limestones, and (*c*) slaty shales of Fiordland had been intruded in the late Permian or early Trias by a tremendous batholith of diorite; and that, as a consequence of later uplift and profound denudation, the ancient Palaeozoic rocks had been broken up into a number of isolated patches that now occupy less than a tenth of the area hitherto ascribed to them. It is in the largest of these remnants, occupying the Preservation–Dusky Sound region, that the graptolitic horizons occur. For the most part the great fiords are drowned cañons carved out of the dioritic complex.

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* *Geol. Mag.* (N.S.), Dec. V, vol. 5, pp. 145–48, April, 1908.

† A. MCKAY, *Mines Report*, C.–11, p. 35, 1896 (N.Z. Blue-book).

‡ J. Park, Geology and Mineral Resources of Western Southland, *N.Z. Geol. Surv. Bull. No. 23* (N.S.), p. 33 *et seq.*, 1921.

WEATHER RESEARCH ON THE KERMADEC ISLANDS.

By D. C. BATES, Director, Dominion Meteorological Office, Wellington.

SUNDAY ISLAND, the largest of the Kermadec Group, lies over six hundred miles north-east of Auckland and half-way to Tonga. My interest in these islands is chiefly concerned in their being utilized for weather-reporting, but I wish to link up economic and scientific possibilities in my remarks on the subject. I am encouraged in this idea by what has been done by Captain John K. Davis, Commonwealth Director of Navigation, in establishing for Australia a meteorological station on the barren islet east of the Queensland coast known as Willis Island, solely for the purpose of weather-observation. We would also have the somewhat problematic but attractive possibility of our station being made a productive and economic success. Although the Government has decided not to deal at the present time with the matter of leasing the island, inquiries are coming from all over the world with regard to it, and while I was in London in 1918 inquiries came to me through the High Commissioner about the prospects of settlement.

First of all I would say that wireless makes all the difference in the world with regard to the prospects for both weather research and settlement. The great difficulty in the past has been infrequency and uncertainty of means of communication; but with, on the one hand, reliable weather conditions, and, on the other, produce ready for shipment, markets could be assured. Long ago the Right Hon. W. F. Massey said, "Sunday Island is one of the outposts of the Empire, and ought to be inhabited if any one is willing to take up his residence there."

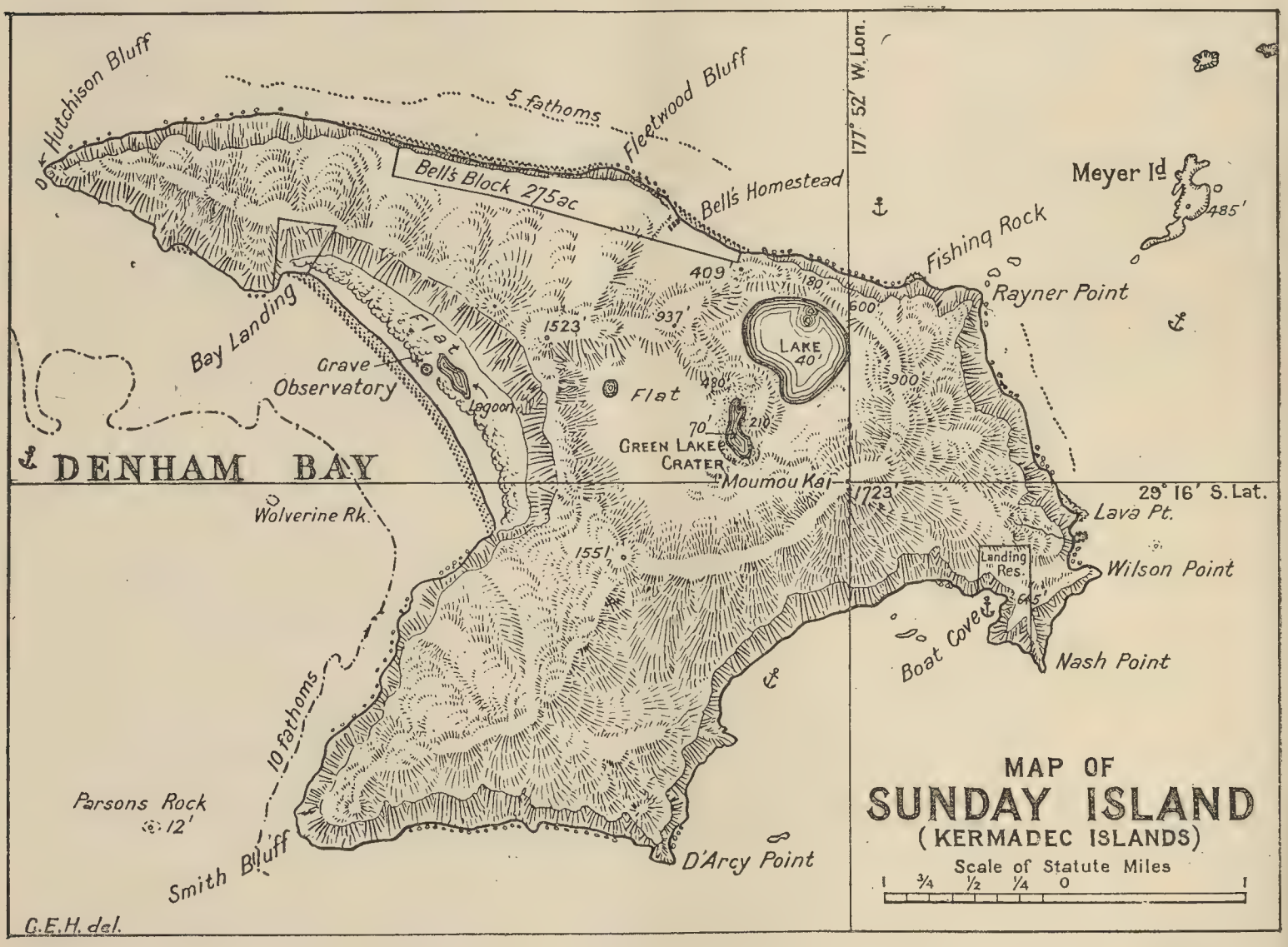
The first discovery of islands in the Kermadec Group was made by the British ship "Lady Penrhyn" in May, 1788; but the largest and only inhabitable island of the group was discovered by a French expedition in 1793. It was first named Recherche Island by the French Admiral, but it was afterwards named Raoul Island, after a member of his staff. Later on it was rediscovered by the British ship "Britannia," whose officers, thinking they were the first and therefore entitled to name it, called it Sunday Island, from the day (6th March, 1796) when they reached it. It was later much frequented by whalers, and settlers were found there as early as 1837. When the whaling ceased the island became isolated, and the settlers came and went away again from one reason or another: thus in 1853 and in 1869 they fled in fear from eruptions of the volcano on the island. Another calamity occurred in 1861 through the landing of two hundred slaves from a Portuguese ship. These people had been forcibly repelled from Tonga, for they were suffering from a pestilence of a typhus nature, and all succumbed. Half the settlers also perished, so that the remainder were glad to escape with their lives on the first opportunity.

The island is apparently of volcanic origin, and the last outburst seems to have taken place in 1872, when a small islet was thrown up in Denham Bay, the remains of which are now known as the Wolverine Rock. Earthquakes occur from time to time—perhaps once a month, judging from the records of the Oliver Expedition in 1908—and there are fumaroles about the island, which constantly emit steam.

Sunday Island has an area of about 7,260 acres, but is mountainous and with few flat surfaces. The three places recognized as landings are

not good: the best (especially in a southerly wind) is at Fishing Rock, on the north, but in easterly weather a landing may be made in Denham Bay, which is on the west coast. One landing is of no use to another, for almost impassable barriers separate them. There are no harbours, and ships must run for shelter to the lee of the island. It is from one hundred to three hundred miles out of the tracks of vessels sailing northward from New Zealand, and until its trade is developed would be dependent upon Government encouragement, or the regular visit of the steamers visiting the food-depots located in the group for shipwrecked mariners.

Apart from weather-reporting, the question which many people will ask is, "Is it worth while?" This question is not easy to answer definitely one way or another, and must be regarded from many different aspects.



The soil is undoubtedly productive and the climate most genial, but there is a shortage of streams and lakes, principally on account of the porosity of the soil. There are two crater-lakes full of water, but both are rather inaccessible, and the lagoon in Denham Bay is cut off from the greater part of the island by lofty cliffs. There is said to be a permanently running stream on the east side of the island, but the land is very hilly. The rainfall, judging from the records, is by no means deficient; but Mrs. Bell, who lived on the island for over thirty years, said she remembered a five-months drought. Storage of water, however, in suitable tanks would surely not prove an insuperable difficulty. Fruits of many kinds—oranges, bananas, and lemons—grow most luxuriantly. Kumaras and potatoes, as well as maize and other cereals, have been produced; but alas! the native rat infests the place and proves very destructive. Hundreds of rats have been caught in a single night; and on this account the bananas, for instance, have to be gathered before they are ripe, and stored in rat-proof *patakas*. The timber-trees appear to be small and not of great commercial value. The whalers and early settlers introduced common and Angora

[*W. L. Wallace, photo.*

DENHAM BAY, SUNDAY ISLAND, LOOKING TOWARDS THE NORTH-WEST END.

[*W. L. Wallace, photo.*

INTERIOR OF CRATER, SUNDAY ISLAND. GREEN LAKE IN FOREGROUND, BLUE LAKE BEYOND.

goats on to the island: these have increased and grown wild. There are now small herds of about twenty head scattered through the various gullies of the island, in which they find definite haunts. In addition to these, mutton-birds provide a welcome change of diet, and fish is abundant on the coast.

Recent history tells how the commander of the German raider "Wolfe" took the mail-boat "Wairuna" to the Kermadecs, and, after transferring his prisoners to the pirate ship, took what he chose from her cargo and sank the vessel. Later Von Luckner and other German escapees from Motuihi Island made for the Kermadecs in their attempt to get away, and were captured on the spot. This year a shipwrecked crew was rescued from Sunday Island; and it is alleged that the depot which is maintained on one of the islands for the use of shipwrecked mariners was looted by a party on the yacht "Raata." Mr. W. R. B. Oliver, with four companions, spent nine months in scientific research there in 1908. Mr. C. E. Warden acted as meteorologist, and I have only recently obtained copies of the meteorological records, which prove a most valuable contribution to this subject.

In 1889 Mr. H. K. Hovell led an expedition for settlement, and kept meteorological records, but these are not now available. I received only this week a long and interesting letter from him on the subject, from which I venture to make a few extracts which are of interest:—

"About the 20th October, 1889, the schooner 'Dunedin' entered Denham Bay after an eventful voyage, bearing within her wooden walls twenty-five of us settlers (including women and two children). We made a safe landing in one corner of Denham Bay, then proceeded to establish our home, after our stores and materials had been landed, and watched, for the last time, the white sails of our schooner sink beyond the distant rim of the sea. This was her last voyage, as she went down carrying with her all hands, but how and where no one can tell—only the Great Master. We established our homes near or on the borders of the small lake which I called 'Destiny.' It is situated about the centre of the bay. Between it and the ocean-rollers was a barrier of sand and shingle, along which grew pohutukawas. On this raised barrier, between the lake and the sea, was visible a mound of stones, across which a wooden cross had fallen through decay, with a sheet of solid copper still endeavouring to cling to it. Upon the plate was beautifully engraved the following:—

SACRED TO THE MEMORY OF

FLEETWOOD JAMES DENHAM

the Beloved Son of Henry Mangles Denham, Captain of Her Britannic Majesty's ship 'Herald,' and Isabella Denham. He died on board the 'Herald' at this Island on the 8th day of July, 1854, aged 16 years, leaving an afflicted parent to mourn his loss here and many at Home who dearly loved him. This tablet is erected by his bereaved Father and Shipmates as a last testimony of their esteem.

Sunday Island, South Pacific, July 9th, 1854.

"Heavy rain fell last night (6th November, 1889). The thermometer has never been below 64° on the coldest nights. To-day we watched a great struggle between a shark and a turtle about 40 yards off the beach. The sea is alive with sharks.

"While proceeding with the station-house we heard a strange sound like the murmuring of a rivulet over stones. On proceeding out to the sand-barrier a remarkable sight presented itself: thousands upon thousands of black-cap terns were arriving and settling on the sands, nesting. We proceeded to the sands and collected hundreds of eggs. The birds were

quite tame, and frequently picked at my hand when taking the eggs from under them.

"To-day (10th November) we watched the whales playing in the bay—counted forty. These lonely waters appear to be a breeding-place for them. We put down some thousand eggs in a 30-gallon cask for future consumption; we now gather them in clothes-baskets.

"I noticed to-day (12th November) a remarkable feature about a well I had put down yesterday to a depth of 10 ft.: the water rises and falls every twelve hours*; the temperature of the water is 82° F., and is decidedly unpleasant to drink, owing to mineral properties.

"To-night the sand in Denham Bay was black with birds, thousands having arrived this afternoon. Thousands of birds have left (14th November), but the north-west corner of Denham Bay is still covered with the late arrivals.

"(16th November): All settlers engaged drawing goods up from landing camp, using a spring cart, the men taking the place of horses, as there are no horses on the island. Heavy rain fell between 1 and 2 p.m., after which brought up another load with the cart. Cutting palm-leaves for thatching.

"(Sunday, 17th November): Self and wife visited Fleetwood's grave. I had made a fresh cross, and polished the copper plate and nailed it to the cross. We placed it at the head of the grave, and collected and placed a cross, consisting of white coral, on the grave."

Other records show that on the 18th December, 1889, the s.s. "Wainui" left Auckland for Sunday Island with five settlers (two women and three children); and on the 28th April, 1890, the s.s. "Hinemoa" arrived from the Kermadecs at Auckland with thirteen of the settlers of Sunday Island.

The most human interest, however, is concerned with the pathetic and specious but at the same time preposterous claims of the late Thomas Bell, who lived for many years upon the island and asserted possession of the land by right of occupancy. He settled there with his family in 1878, when there were no other inhabitants, and only finally left it at the end of June, 1914. He claimed to have saved the island from German annexation, and his claims were so uncommon and made with such importunity over a long period that controversies on points of the highest importance arose from time to time. One can only feel sorry for the poor old man, who died about two years ago at the age of eighty-four. To his dying day, and in spite of various transactions by which any ordinary person would have parted with every vestige of title, he maintained his rights and grievances against all comers, and particularly against the Crown, which in 1898 granted him a certificate of title to 275 acres freehold and the lease of the whole island at 10s. per annum. In 1901 Bell sold his rights to the freehold for £50, and the lease for £350. In 1903 he petitioned the House, and later obtained another £50 in settlement of all claims. Previously, in 1894, Dunedin people promoted a company, called "T. Bell Company," and lost over £2,000 in the venture. After such an experience with various settlers it is no wonder that the Government hesitates to deal with the island, and declares that it is not now dealing with any leases. I trust, however, that some way will be found out of the difficulty, and that Sunday Island may have a permanent meteorological observatory surrounded by a small but contented and thriving community. I feel quite certain that at some future day we must have a weather-reporting station on Sunday Island, because it lies in the path of many tropical storms that affect our weather and particularly concern the Hawke's Bay District. There are

* With the tides of the sea.—D. C. B.

several clear proofs of this in the records of this expedition of 1908. I will examine these as briefly as possible :—

February, 1908, was the driest and one of the hottest months on record in New Zealand, but was not dry on Sunday Island, for 6·79 in. of rain was registered on seventeen days, with maximum falls of 1·62 in. on the 10th and 2·42 in. on the 11th ; and the fact to be noted is that the best rainfalls of the month followed in Hawke's Bay on the 12th and 13th.

March brought the end of the Dominion drought, and on the 20th I recorded that a cyclone made its appearance off East Cape and brought rains to all the coastal stations of Hawke's Bay. These falls were remarkably heavy ; and cyclonic conditions prevailed in the North Island until the 28th, and between the 18th and 26th, on the southern edge of these disturbances, Wainuiomata had the tropical quantity of 17·37 in.

When we turn to the Sunday Island records we see that on the 10th a north-east gale was registered at Denham Bay, 675 miles being recorded on the anemometer and 181 points in the rain-gauge ; and on the 13th 1·92 in., with only 65 miles of wind for the twenty-four hours. There seem to have been disturbances following in each other's tracks. On the 16th, 17th, and 18th the wind-velocities were respectively 516, 496, and 482 miles per day, with but little rain. The centre of the depression was then, I believe, to the eastward of the island and travelling towards East Cape, where the record shows that it was in evidence at 4 p.m. on the 20th. On the 19th 4·15 in. of rain fell at Gisborne, and considerable rain also was reported as far south as Canterbury between the 20th and 22nd. Thus since we have the Sunday Island records we are in touch with the storm for over a week.

April rainfall totalled 11·30 in. on the island, 3·56 in. of which fell in a local thunderstorm on the 27th. It may be noted that at that time there was an extensive low pressure with little wind and without much gradient over New Zealand. In the early part of the month there was an extensive anticyclone over most of the Dominion, which probably warded off the storm which appears to have existed to the eastward of Sunday Island and accounted for several inches of rain.

May rains in New Zealand mostly came from westerly disturbances which did not affect the east coast. There were, however, 6·81 in. of rain on Sunday Island on twenty-two days, with only two falls above 1 in. The highest wind during the month was only 251 miles per day, and so we may conclude that the westerlies dominated the situation.

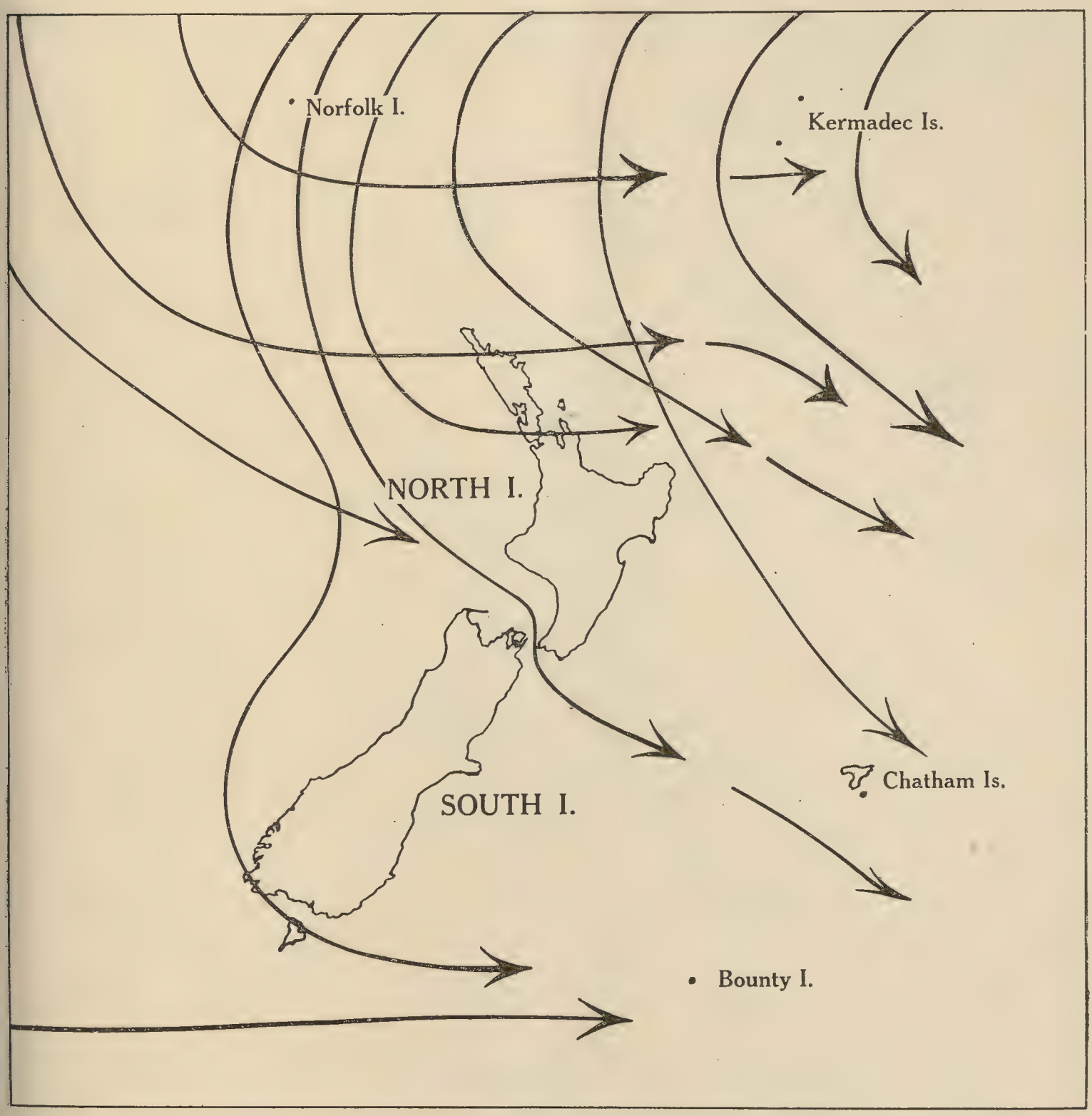
June was also dry on the east coast of New Zealand, but I made a note in the *New Zealand Gazette* at the time that there was a cyclone off East Cape between the 18th and 20th, though an anticyclone covered New Zealand, and that low pressures were probably passing eastward of the Dominion in the latter half of the month, accounting for that cold and humid type of weather which we describe as "raw." It is remarkable that the wind was in the west at Denham Bay during this period, and that the barometer record shows that three distinct disturbances passed eastward of the island on the edge of our anticyclone.

July is the midwinter month of the Southern Hemisphere, and though the greatest number of rainy days (twenty-seven) was experienced on the island and the total was 6·43 in., yet only twice did the fall exceed 1 in. These records, together with a rather lower barometric pressure, showed the predominating influence of the great south-westerly drift of the atmosphere, which often extends northward at that season and does not usually carry ex-tropical storms.

The relation, therefore, between the island weather and that of the Dominion is one that gives New Zealand indications of special value for

ocean forecast as well as to the island itself. It is to be remembered that the Meteorological Office of this Dominion broadcasts ocean weather forecasts from Awanui, in the extreme north of New Zealand, and we need information from the seas as a basis for these forecasts.

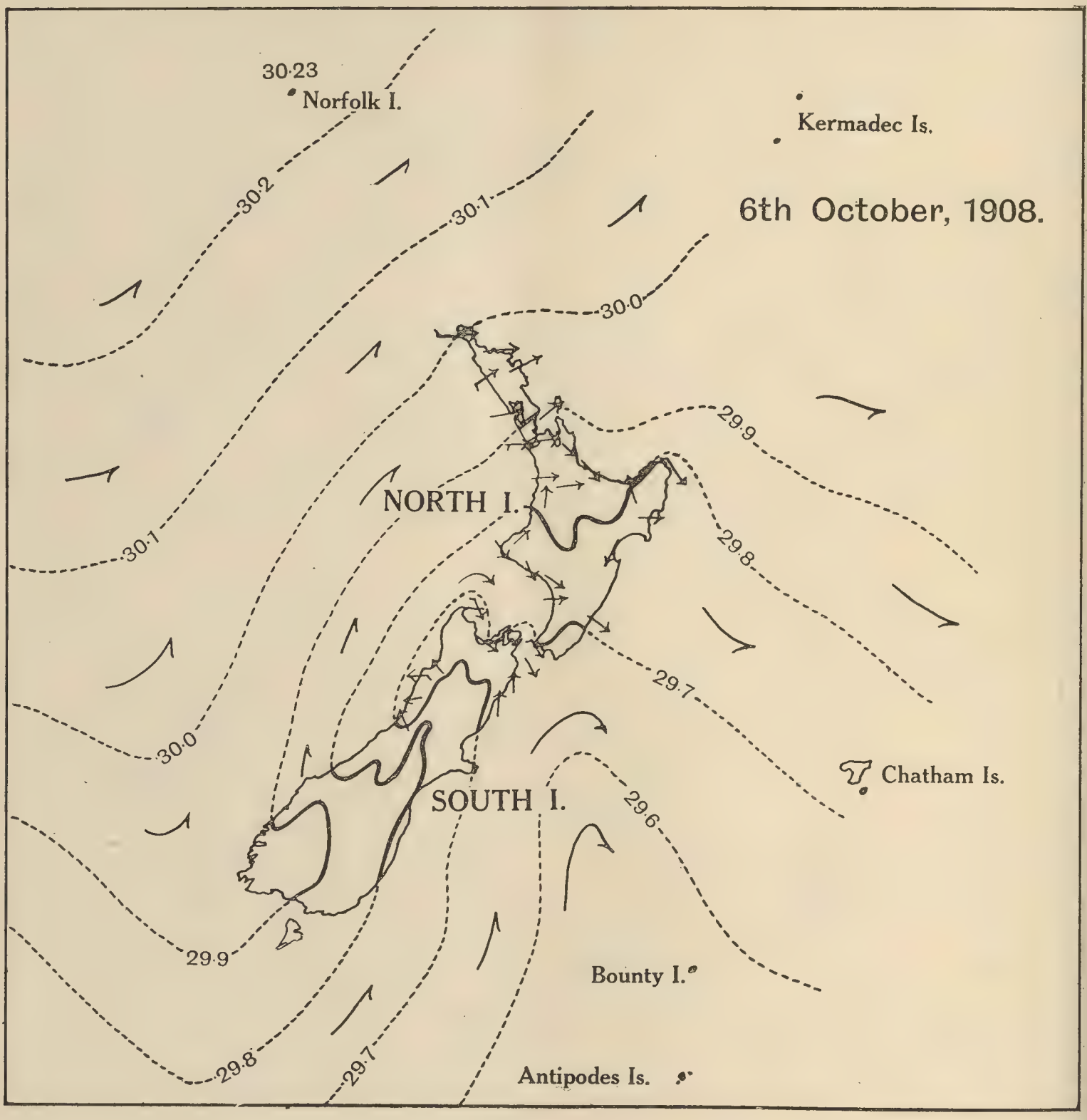
To show, however, that there is no absolute rule that cyclones only occur in summer months, we find that in the month of August we have a record of a tropical cyclone passing in the vicinity of Sunday Island, when the barometer fell over 1 in. in forty-eight hours—30·330 in. on the 9th to



29·319 in. on the 11th—though there was only a dip of 0·38 in. in seven hours at Russell, after which the barometer immediately rose. The records at Denham Bay at 9 a.m. show,—

Date.	Barometer.	Winds.	Mileage.	Cloud.	Rain (Inches).
August 10	29·931	East ..	286	10	0·88
,, 11	29·319	North-west	662	10	0·86
,, 12	29·447	South-west	648	9	0·77
,, 13	29·952	South ..	363	10	0·52

This storm undoubtedly passed eastward of New Zealand, but affected the weather on the east coast of the North Island, for there were heavy seas and high tides at East Cape for a day or two afterwards, and many useful falls of about 1 in. of rain were recorded. The connection between weather conditions of the mainland and Sunday Island is, however, more plainly seen from a storm which passed between them between the 3rd and 8th and accounted for both wind and rain; but our own reports gave

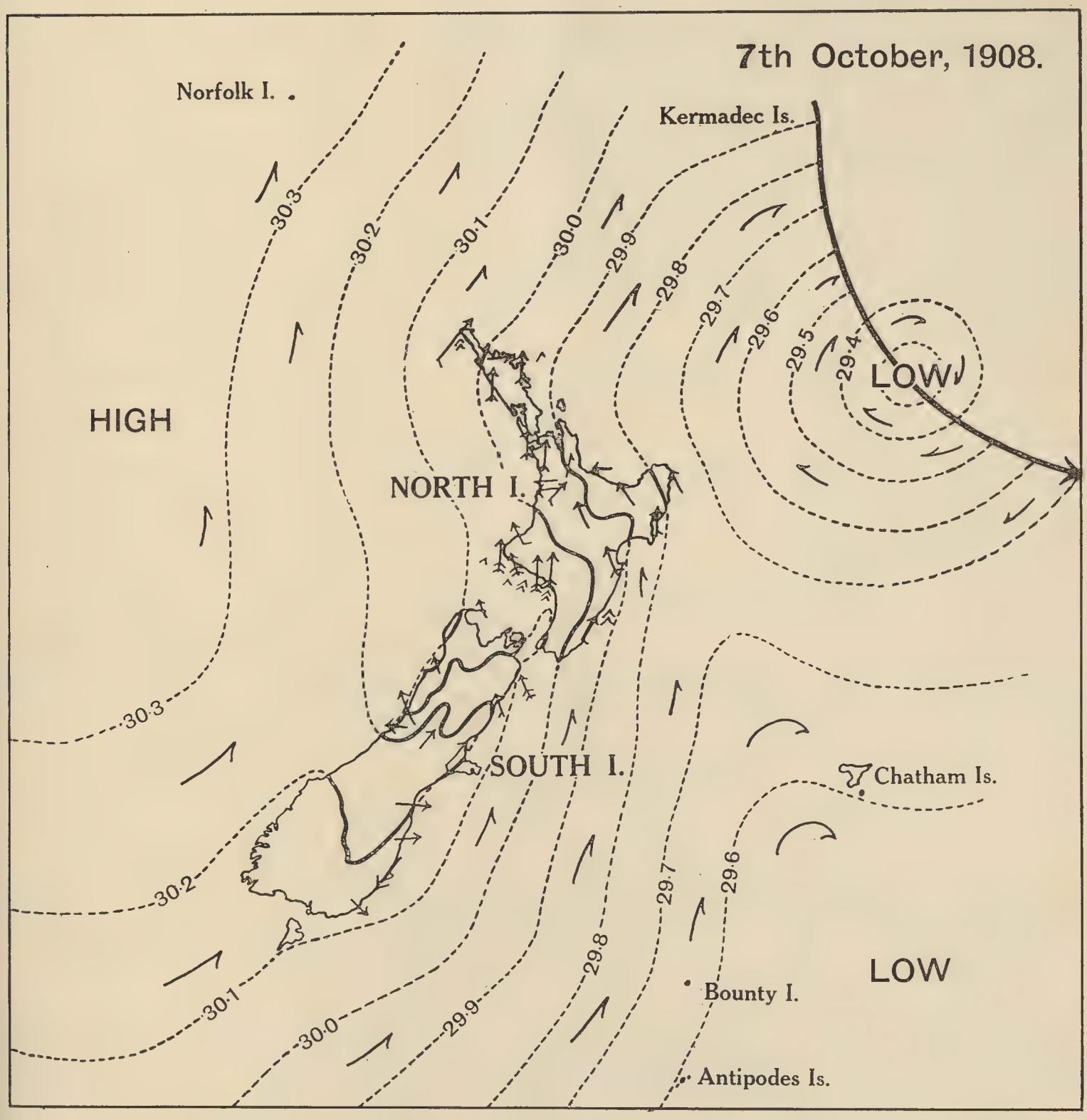


sufficient warning in this case apart from what we might have had from a Kermadec station.

In September a westerly type of weather again prevailed over the Dominion, but high pressure ruled mostly on Sunday Island, and though rain fell on twenty days and 1·90 in. on one of them, the total was only 3·91 in. Effects of disturbances passing over New Zealand were in evidence at Sunday Island, and show the extension of the westerly atmospheric drift, which sweeps round the world in what is known as the "roaring forties," but in winter-time will occasionally reach the "thirties."

October: I have a record of another cyclone off East Cape on the 7th October, and it was in evidence on Sunday Island three days earlier:

2·19 in. of rain were recorded there on the morning of the 5th. Considerable rain followed in Hawke's Bay from this disturbance, but until the morning of the 7th we had nothing whereby to show it, or on which to surmise its existence, and even then a cyclone was not a certainty. The same thing occurred on the 17th. There was nothing on our charts to indicate a cyclone at the Kermadecs, but we found one off the East Cape on the morning of the 19th. Mr. Warden measured 2·60 in. of rain on the morning



of the 16th, and 1·89 in. on the 17th, while the anemometer recorded 562 miles for the twenty-four hours preceding 9 a.m. on the 18th, 571 on the 19th, 332 on the 20th, and 75 on the 21st, when the westerly wind had died down and the sky cleared at Sunday Island.

In preparing this paper I desire to acknowledge my indebtedness to the late Mr. Percy Smith, F.R.G.S., and his son, Mr. M. Compton Smith, for valuable information; to Messrs. W. R. B. Oliver, F.L.S., C. E. Warden, K. H. Hovell, Captain George Hooper, R.N.R., and lastly to Mr. W. W. Goudie, F.R.Met.Soc., who assisted me in preparing the records and the table herewith showing the results of the observations of 1908.

METEOROLOGICAL OBSERVATIONS TAKEN AT DENHAM BAY, SUNDAY ISLAND, DURING 1908.

(Observer, C. E. Warden.)

Lat., S. 29° 15′; long., W. 177° 55′. Altitude above sea, 5 ft. Observations taken at 9 a.m.

Month.	Atmospheric Pressure (reduced and corrected). Standard Barometer (Casella 2293).						Temperature from Self-registering Instruments for Twenty-four Hours previous (corrected).											Mean Humidity[1] (Sat.=100).
							Temperature of Air in Shade.									Humidity, 9 a.m.		
	Mean Height of Barometer.	Max.	Date.	Min.	Date.	Extreme Range.	Mean Max.	Mean Min.	Mean Temp. for Month.	Mean Daily Range.	Extreme Max.	Date.	Extreme Min.	Date.	Extreme Range.	Dry Bulb.	Wet Bulb.	
1908.	Inches.	Inches.		Inches.		Inches.												
February ..	29·930	30·133	23	29·546	13	0·587	78·8	68·6	73·7	10·2	84·9	2	63·5	2	21·4	74·7	70·8	79
March ..	29·862	30·178	2	29·621	18	0·557	78·4	66·2	72·3	12·2	82·5	30	59·3	19	23·2	73·4	71·6	90
April ..	30·042	30·257	13	29·729	8	0·528	75·7	62·0	68·8	13·7	81·2	1	54·8	12	26·4	69·6	68·8	95
May ..	30·125	30·400	19	29·815	6	0·585	71·2	59·9	65·5	11·3	77·6	8	52·6	24	25·0	65·1	64·5	96
June ..	30·042	30·450	4	29·695	28	0·755	68·3	58·8	63·5	9·5	71·9	29	53·6	23	18·3	63·8	62·7	94
July ..	29·938	30·209	11	29·426	30	0·783	68·7	54·4	61·5	14·3	73·4	12	49·4	22	24·0	60·4	60·1	98
August ..	30·027	30·330	9	29·319	11	1·011	66·1	54·4	60·2	11·7	69·9	21	46·1	4	23·8	60·2	58·7	91
September ..	30·191	30·438	8	29·797	23	0·641	67·9	53·3	60·6	14·6	73·5	11	47·2	26	26·3	62·2	59·5	84
October ..	29·993	30·235	2	29·686	18	0·549	71·0	57·3	64·1	13·7	77·8	31	49·6	21	28·2	65·2	63·2	88
Means, &c...	30·017	30·450	4 June	29·319	11 Aug.	1·131	71·8	59·4	65·6	12·3	84·9	2 Feb.	46·1	4 Aug.	38·8	66·1	64·4	91

Month.	Rain.				Mean Cloud. (0 = clear sky; 10 = overcast.)	Wind.											Gales or High Winds.	Thunder.	Snow.	Hail.	Fog.
	Total Fall in Month.	Number of Days of Rain.	Max. Fall in any Twenty-four Hours.	Date.		Average Daily Velocity, in Miles, for Month.	Max. Velocity, in Miles, in any Twenty-four Hours, and Date.	Number of Days it blew from any Point.													
								N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	Calm.	Total Days.					
1908.	Inches.	Days.	Inches.			Miles.	Miles.											Dys.	Dys.	Dys.	Dys.	Dys.
February ..	6·79	17	2·42	11	5·8	230	398; 14	1	4	15	2	2	1	1	3	..	29	..	..	..	..	1
March ..	6·88	17	1·92	13	5·2	225	675; 10	4	10	5	2	1	4	4	1	..	31	..	..	..	..	..
April ..	11·30	18	3·56	27	5·4	129	427; 9	2	1	14	3	1	3	2	1	3	30	..	2	..	..	..
May ..	6·81	22	1·49	30	6·6	115	301; 7	3	..	5	11	3	..	5	3	1	31	..	1	..	..	..
June ..	5·91	21	2·54	9	7·5	178	399; 7	2	4	3	1	1	5	7	5	2	30	..	2	..	..	..
July ..	6·43	27	1·58	29	6·2	284	581; 18	2	..	..	1	1	3	15	8	1	31	..	..	..	..	..
August ..	9·36	20	1·44	26	7·3	274	662; 11	3	..	8	1	4	2	8	5	..	31	..	1	..	..	..
September ..	3·91	20	1·90	28	5·7	166	440; 18	4	2	8	5	2	1	5	2	1	30	..	..	..	..	..
October ..	8·87	24	2·60	16	5·6	266	571; 19	2	1	3	2	1	4	14	4	..	31	..	1	..	..	..
Means, &c.*	66·26	186	3·56	27 April	6·1	207	675 10 Mar.	23	22	61	28	16	23	61	32	8	274	..	7	..	..	1

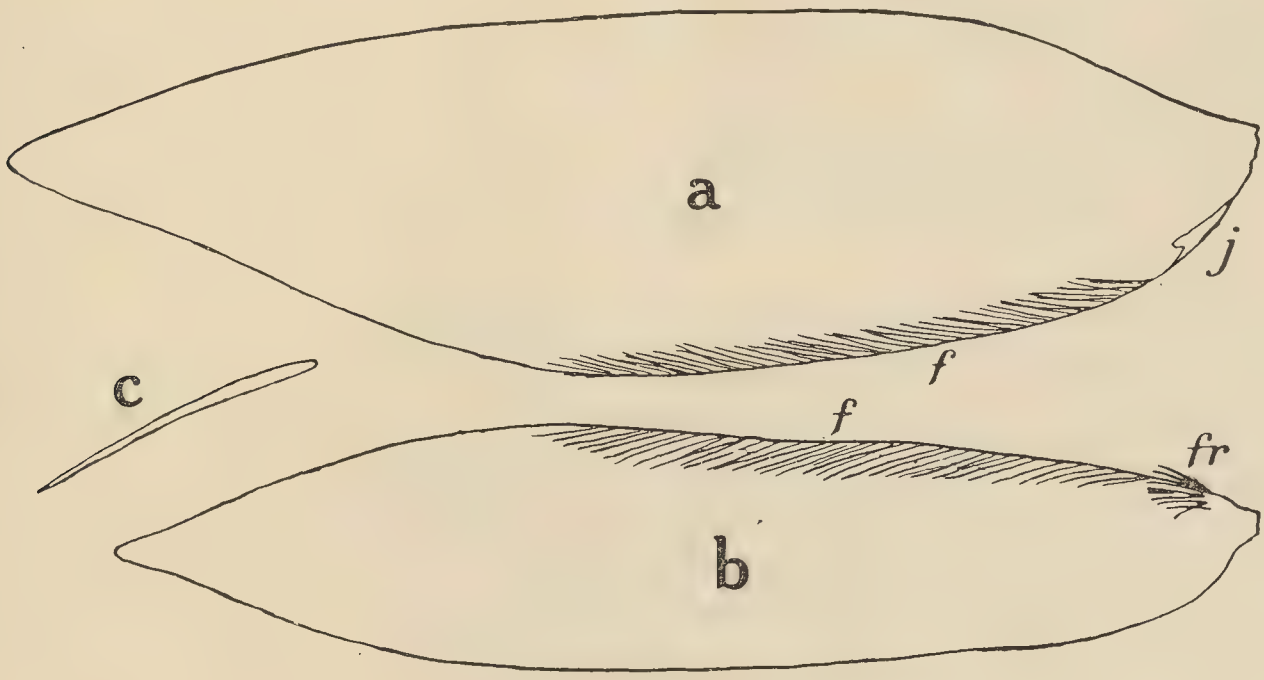
* Totals and means for nine months.

THE WING-COUPLING APPARATUS IN THE MNESARCHAEIDAE.

By ALFRED PHILPOTT, F.E.S., Cawthron Institute, Nelson.

THE Mnesarchaeidae are a family of Lepidoptera characterized by very high specialization in the wing-venation. Tillyard (*Proc. Linn. Soc. N.S.W.*, vol. 44, p. 650) has tabulated the venational characters for all the families of the Heteroneura, and shows that the percentage of archetypic characters present in the Mnesarchaeidae is only 17·5, while in the other four families it varies from 37·5 in the Prototheoridae to 72·5 in the Micropterygidae.*

While studying the venation of the genus *Mnesarchaea* the attention of the writer was drawn to the very feeble-looking jugal lobe. It seemed



Wing-coupling apparatus of *Mnesarchaea hamadelpha* Meyr.: *a*, forewing, under side; *b*, hindwing, upper side; *c*, a single frenular hair; *f*, fringe of coupling-hairs; *fr*, frenular hairs; *j*, jugal lobe.

inadequate as a coupling-apparatus, and an investigation was commenced with the object of ascertaining if any other method of linking the wings together during flight was present. The search resulted in the discovery of a secondary apparatus, which is described in this paper, and also in a better understanding of the way in which the jugal lobe functions in this genus.

As shown in the text-figure, the lobe is quite small, and is situated on the basal curve of the dorsum. Its position makes it difficult to under-

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* Since the publication of Dr. Tillyard's paper Dr. A. Jefferis Turner has created two new families, the Palaeosetidae and the Anomosetidae, in which to place two extremely interesting moths discovered by him in the Queensland National Park. These two families have a percentage of archetypic characters of 35 and 30 respectively. Owing to Dr. Turner's kindness I have been able to examine the neuration of *Palaeoses*; the calculation of the percentage in *Anomoses* was made from Dr. Turner's figure in the *Proc. Ent. Soc. Lond.* (1922), p. 600.

stand how frenular bristles on the costa of the hindwing could lie within its groove unless the hindwing were held almost at right angles to the forewing, a position in which the wings would only be in contact at the extreme base. An examination, however, of a large number of specimens has shown me that the jugal lobe in *Mnesarchaea* is not recurved at all tightly, being only bent round to slightly more than a right angle with the plane of the wing. It thus forms not a tight finger-and-thumb grip for the bristles, but a catch or projection against which they press.

The frenular bristles do not spring from the edge of the costa, but from just beneath it. About twenty stiff but short hairs rise in a bunch, being directed backward along the wing, and not, as is usual, projecting obliquely above the costa. From their position, when both wings are spread, they would lie in the concave anal area of the forewing, the apical portion of the jugal lobe being of service as a stay or spring beneath them. Though these hairs function as frenular bristles, they are not like the bristles usually constituting the frenulum in Lepidoptera. They are short, and obtuse at the apex, and also thinner at the base than throughout their length (see figure). Nor can I discover that their bases differ in any way from those of the ordinary scales.

But though the above view of the functioning of the jugal lobe and frenulum may be more consistent with the position and shape of the structures, the apparatus still presents a weak and unsatisfactory appearance. It is, however, efficiently assisted by the secondary coupling which is now to be described.

Along the under side of the dorsum of the forewing, for about half its length, is a fringe of long hairs directed backward and slightly upward and outward, while on the upper side of the costa of the hindwing is a similar fringe, also directed backward but slightly downward. It will be seen, therefore, that when the wings are extended in flight the fringe of hair on the costa of the hindwing will lock into that of the forewing, forming a strong and, at the same time, elastic coupling.

We have, then, in the wing-coupling apparatus of *Mnesarchaea* a further example of extreme specialization. As far as I am aware, such a type of wing-coupling has not been observed in any other lepidopterous group.

It might be added that immediately distad of the jugal lobe there is a small area densely covered with minute tubercles. These are modified microtrichia, and at first sight the obvious conclusion appears to be that this roughened patch is of use in assisting to hold the frenular bristles in place. But apart from the fact that the tubercles are too small to be of much use, and also that they are more or less covered by the scales, it has to be remembered that a similar tuberculated area is to be found in the same position on the hindwing; and, further, that many of the Heteroneura possess the same structure, the frenular hairs in their case being in such a position as prevents any contact with the roughened area.

RADIO-INSTALLATION RULES.

Abstract of Report of Standing Committee of U.S. National Fire Protection Association.

A COMMITTEE of the National Board of Fire Underwriters (U.S.A.) has made certain tentative recommendations for revision of Rule 86 of the National Electrical Code covering radio-installations. These recommendations were recently discussed by the Bureau of Standards Engineers; and, as it is understood that the National Fire Protection Association will be pleased to have suggestions for improvements, a brief precis of the proposed revision of Rule 86 of the National Electrical Code, together with the Bureau of Standards Engineers' discussion, is given below.

RADIO EQUIPMENT.

(NOTE.—These rules do not apply to radio equipment installed on shipboard.)

In setting up radio equipment all wiring pertaining thereto must conform to the general requirements of this code for the class of work installed and the following additional specifications.

Receiving Stations only.

(*a.*) *Antenna.*—Antennas outside of buildings shall not cross over or under electric-power wires of more than 600 volts, or railway-trolly or feeder wires. Antennas shall be constructed in a strong and durable manner, and so located as to prevent accidental contact with the light and power wires. Splices and joints in the antenna span, unless made with approved clamps or splicing-devices, shall be soldered.

Antennas installed inside buildings are not covered by the above specifications.

(*b.*) *Lead-in Wires.*—Lead-in wires shall be of copper or other approved metal which will not corrode excessively, and shall be of a minimum size of 14 and 17 B. and S. respectively. Lead-in wires must not come nearer than 4 in. to electric light and power wires unless permanently separated by continuous insulation. Lead-in wires shall enter the building through a non-combustible, non-absorptive insulating bushing.

(*c.*) *Protective Device.*—Each lead-in wire shall be provided with an approved protective device consisting of an approved lightning-arrester which will operate at a potential of 500 volts or less. The use of an antenna grounding-switch is desirable, and, if installed, shall, in its closed position, form a shunt round the protective device. A ground-switch does not obviate the necessity for a lightning-arrester.

(*d.*) *Protective Ground-wire.*—The ground-wire may be bare or insulated, and shall be of copper or approved copper-clad steel of a minimum size of 14 and 17 B. and S. respectively. The ground-wire shall run in as straight a line as possible to a good permanent ground, preferably to water-piping.

(*e.*) *Wires inside Buildings.*—The inside wiring shall be permanently fastened, and shall not come nearer than 2 in. to any electric light or power wire unless permanently insulated therefrom.

(*f.*) *Receiving-equipment Ground-wire.*—The ground conductor may be bare or insulated, and shall be of copper or other approved metal which will not corrode excessively, and according to the size specified.

Transmitting Stations.

(*g.*) *Antenna.*—The regulations are the same as for antennas for receiving stations.

(*h.*) *Lead-in Wires.*—Antenna and counterpoise conductors, and wires leading therefrom to ground-switch, where attached to buildings, must be at least 5 in. clear of the surface of the buildings, firmly mounted on non-absorptive insulating supports, or approved suspension-type insulators. In passing the antenna or counterpoise lead-in into the building a non-absorptive insulating bushing shall be used.

(*j.*) *Protective Grounding-switch.*—A double-throw knife switch shall be used to join the antenna and counterpoise lead-ins to the ground conductor. The switch must be mounted so that its current-carrying parts will be at least 5 in. clear of the buildings. Slate base switches are not recommended.

(*k.*) *Protective Ground-wire.*—Antenna and counterpoise conductors must be effectively and permanently grounded when station is not in actual operation (unattended).

(*l.*) *Operating Ground-wire.*—The radio operating ground conductor shall be of copper strip not less than $\frac{3}{8}$ in. wide by $\frac{1}{64}$ in. thick, or copper or copper-clad steel having a periphery of at least $\frac{3}{4}$ in.

(*m.*) *Operating Ground.*—The operating ground conductor shall be connected to a good permanent earth, preferably water-piping. Gas-piping shall not be used for ground connections. Grounded steel frames of buildings and artificial grounding-devices are permissible.

(*n.*) *Power from Street-mains.*—When the current-supply is obtained directly from street-mains the circuit shall be installed in approved metal conduit, armoured cable, or metal raceways. Lead-covered wire shall be protected in metal conduit or metal raceways.

(*o.*) *Protection from Surges.*—In order to protect the supply system from high potential surges and kick-backs there must be installed in the supply line, as near as possible to each radio-transformer, rotary spark-gap, motor generator set, and other auxiliary apparatus, one of the following :—

(1.) Two condensers in series across the line, with the midpoint between the condensers grounded ; across each condenser should be connected a shunting fixed spark-gap of $\frac{1}{32}$ in. :

(2.) Two vacuum-tube-type protectors in series across line, with the the midpoint grounded :

(3.) Non-inductively-wound resistors connected across the line, with the midpoint grounded :

(4.) Electrolytic lightning-arresters.

In no case shall the ground-wire of surge and kick-back protective devices be connected to the operating ground or ground-wire, or run parallel with the operating ground-wire when within a distance of 30 ft.

(*p.*) *Suitable Devices.*—All apparatus employed shall be of types suitable for radio-operation.

DISCUSSION AND EXPLANATION BY THE BUREAU OF STANDARDS ENGINEERS OF THE ABOVE PROPOSED REVISION OF RULE 86 ON RADIO EQUIPMENT.

These rules do not apply to radio equipment installed on shipboard, but have been prepared with reference to land stations.

Receiving Equipment.

(*a.*) *Antenna.*—Indoor receiving antennas are not included within the requirements of this proposed rule, which provides for the protection of a radio equipment against lightning and high-power wires. Indoor receiving antennas are included in the general requirements covering the wiring of signal systems. It is desirable that electrical-construction companies install radio antennas and apparatus for persons who are not familiar with electric wiring. This will tend to ensure the installation of apparatus in a strong and durable manner. It is important that antenna wire should be of such size and tensile strength as to avoid its contacting with any electric-power wires whatsoever, but the size and material of which the antenna is made should depend to some extent upon the length of the span. The requirements covering splices and joints in the antenna span are to avoid accidental falling of such wires upon light or power wires of not less than 600 volts where it is found necessary to cross such lines. It will be noted that the rules permit crossings with lines of 600 volts or less if they are not trolly-wires or feeders to trolly-wires.

(*b.*) *Lead-in Wires.*—The provision for running the lead-in wires through a bushing is chiefly to protect the wiring against the possibility of short-circuiting with electric-power wires which may run in the wall and whose location may be unknown to the persons installing the radio equipment.

(*c.*) *Protective Device.*—The requirements for a protective device to be connected between the antenna and the ground terminals of the receiving set are for the purpose of carrying lightning-discharges, or less violent discharges caused by induction or by atmospheric electricity, to the ground with a minimum chance of damage to the receiving apparatus, building, or operator. A fuse is not necessary. If a fuse lightning-arrester is used it makes it less likely that the antenna terminal of a receiving set will be put at a high voltage in case the antenna falls upon an electric light or power wire. The absence of the fuse, on the other hand, makes it possible for the antenna, if it accidentally falls across the power wires, to become fused at the point of contact, and thus fall to the ground and eliminate the hazard.

Arresters should be enclosed in such a way as to protect the breakdown gap from dust. One disadvantage of the vacuum-tube type of arrester is that it may cease to function without giving warning that it is inoperative. While an arrester connecting between the antenna and ground is regarded by many as sufficient protection, it is somewhat safer to install the switch in parallel with it as an added protection, particularly if the arrester is inside the building and the ground connection is made to a radiator. If the antenna is properly connected to the ground such connection prevents the antenna from becoming a hazard to the building and its contents.

(*d.*) *Protective Ground-wire.*—While it is desirable to run the protective ground-wire in as direct a line to ground as possible, it is more important to provide a satisfactory contact at the ground itself.

(*f.*) *Receiving-equipment Ground-wire.*—If the ground-wire of a receiving set passes through a wall it should be insulated, and if exposed at all to mechanical injury it should be enclosed in wood moulding or other insulating-material for mechanical protection. Ground-wires should not be run through iron pipe or conduit, because of the choking effect at radio and lightning frequencies.

Transmitting Equipment.

(*j.*) *Protective Ground-switch.*—On account of high voltages produced by radio transmitting equipment, it is desirable to provide for the use of a double-throw switch for connecting the antenna either to the transmitting-apparatus or to the ground, thus making it possible to entirely disconnect the antenna from the transmitting apparatus when not in use.

The objection to slate base switches is chiefly from the radio engineering viewpoint, on account of the absorption of water by many kinds of slate and the presence of conducting streaks.

(*o.*) *Protection from Surges, &c.*—On account of the difficulty which has been experienced by the induction of voltages in the supply lines of a transmitting station, it is advisable to use a protective device across the terminals of each machine or transformer connected to this power line. It would also seem desirable to connect a small protective device across the power line and as near the point of its entrance to the building and on the house side of the meters. It is desirable that research on the performance of protective devices and the means for avoiding surges and "kick-backs" in the power-supply lines be promoted.

It will be seen from the above rules that in the United States of America provision is being made for regulations to prevent the possibility of fire from causes which are perhaps seldom recognized.

A. GIBBS.

A NOTE ON THE SIGNIFICANCE OF THE RECENT SUBSIDENCE OF THE SHORE OF LAKE TAUPO.

By RALPH H. WARD, Taupo.

IN view of the attention which has been drawn to the Taupo district by the seismic phenomena of the last five months the following note on the significance of the recent subsidence of the lake-shore at Whakaipo Bay may not be devoid of interest. A study of the western bay of the lake, and an examination of the charts (for which see "Notes on the Physiography and Geology of the King-country," Cussen, *Trans. N.Z. Inst.*, vol. 20, page 316 *et seq.*, and "A Bathymetrical Survey of the Lakes of New Zealand," Lucas, *Jour. Royal Geog. Soc.*, London, 1904, p. 645 *et seq.*) leaves little doubt that the greater part thereof was originally formed by the creation of a great volcanic crater or series of craters. It is equally apparent, however, that the area thus formed has been gradually enlarged by subsidences similar to that which has been going on of late at Whakaipo.

On the north shore of the lake there are four large inlets—namely (from east to west), Tapuaeharuru, Whakaipo, Whangamata, and Kawakawa (or Marae-Kowhai). The Waikato River, the outlet of the lake, flows from the north-west end of Tapuaeharuru Bay. In all these bays old totara-tree trunks may be found submerged, in varying depths of water, and some still protruding above the surface. Their location, and the natural upright position of many of them, shows clearly that they have

been submerged by subsidence, and that they have not been washed into the lake by floods, nor by erosion of the shore. At Whakaipo Bay one partly submerged stump, a well-known landmark to launch-men, has now been completely submerged by the recent subsidence.

The greatest number of such submerged trees is to be found in Tapuaeharuru Bay, in the vicinity of the Waikato outlet. This is the shallowest of the bays, and the formation of the greater portion of it by subsidence is apparent, not only from the evidence of the tree-stumps, but also from the extension into the lake, on both eastern and north-western sides, of the hill-ridges along the shores. These continue out as rocky little reefs and shallows. Further evidence that the lake has fallen to its present level by a fairly rapid subsidence hereabouts, extending some distance down the course of the river, is available at various places; subsidences can also be traced along the eastern shores of the lake.

Without encumbering this note with further details, I would summarize the significance of the facts outlined as follows:—

(1.) The present subsidence at Whakaipo, at a conservative estimate, covers an area probably three miles from east to west, and includes the whole of the peninsula between Whakaipo and Whangamata Bays, approximately two miles and a half from north to south. How far north it extends, back from the lake, has not yet been ascertained. The depth of the subsidence at the beach at the base of the peninsula now averages 9 ft. at least: at the south end of the area it is probably from 2 ft. to 3 ft. Visits made to the locality at intervals during the past few months indicate that the subsidence has probably not been gradual, but that it has proceeded by a succession of sudden "drops."

(2.) A similar subsidence in Tapuaeharuru Bay would have permanently lowered the lake-level by at least 9 ft.: the consequently increased overflow would have caused a series of floods in the Waikato River, varying with the extent of each stage in the subsidence.

(3.) The present seismic disturbance has not been merely local to the Taupo district: observations made by Colonel G. A. Ward, C.B.E., at Tauranga, by means of a pendulum seismometer with an electric "alarm-bell" attachment, go to show that, coincident with many of the earthquakes propagated from local foci, there have been other smaller disturbances, radiating from foci at various points to the north-east of Taupo on the line of the well-known Whakatane fault. This, considered in the light of similar disturbances, here and in the Bay of Plenty, in the past, tends to show that movements along the line of this fault are still liable to be experienced intermittently. And the evidence of lake-shore subsidences outlined above shows that such subsidences are not unlikely to accompany such fault movements.

(4.) With the advent of large hydro-electric schemes the Waikato River is becoming of increased commercial importance, and any possibility of such occurrences as mentioned in (2) above merits very careful attention. In this connection I would urge that the Government should have a series of bench-marks fixed in the vicinity of Tapuaeharuru Bay,* from which the Waikato flows. It would then be an easy matter to ascertain, from time to time, any tendency to elevation or depression in the neighbourhood of the outlet, and so to keep a check on the probability of any alterations in the overflow of the lake.

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* This was done by the Public Works Department in October last on the suggestion of Professor Marsden, who had previously visited the district and closely observed the seismic phenomena.—EDITOR.

INSTINCT AND INHIBITION: THE INTEGRATION OF THE PERSONALITY.*

By STUART MOORE, B.A., M.D., M.R.C.P.

IT is the study of the abnormal in recent years which has been the most important factor in determining the great advances that are at present being made in normal psychology. In this branch of study the normal cannot be understood without reference to the abnormal.

There is one form of hysteria in which the patient feels compelled to think of certain things or to do certain things—*e.g.*, the hypochondriac, who is always talking about his health. He suffers from the dread of disaster in the form of bodily sickness, and even when he knows that his dread is absurd he will, in many cases, feel compelled to go on thinking about it. He is the subject of an obsessive or compulsive thinking. He lacks the power to inhibit this thinking.

Instead of merely thinking and speaking he may be compelled to perform certain acts, such as homicide in extreme cases, or in milder cases he may suffer distress if he does not, *e.g.*, touch each post of a fence as he walks along by it. He is the subject of an obsession, and lacks the power to inhibit the obsessive act.

These patients, however, commonly suffer also from phobias: one is afraid of being in a small room, another of being in a house alone, another of being in the open street. Others have morbid fear of cats, spiders, frogs, clergymen, doctors, or whatnot. These fears and incapacities limit the activities of these patients; and even one such fear, as the fear of going out alone, may interfere seriously with the carrying-out of the life's work. These phobias appear to have no logical foundation, and are often recognized as absurd by the person who is the subject of them. They constitute prohibitions, or inhibitions, from which the person cannot free himself. In treating such patients the problem which confronts the physician is how to supply the power of inhibition for obsessive acts, and to remove the inhibition of the phobias.

We do not, however, need to find patients in order to meet with this problem of how to secure and abolish inhibition at will. We have all done those things which we wished not to have done, and have left undone those things that we wished to do. We have failed to inhibit our impulses when we desired to do so, and have failed likewise to free ourselves from undesired inhibitions.

When an attempt is made by a man to modify the behaviour of others, or of himself, the problem of inhibition, its creation and its removal, is fundamental. Hence it is that this rather technical word "inhibition" appears in the title of this paper.

Some years back there was a tendency to regard mind as the prerogative of man, but nowadays we are taught that even animalcules like the amoeba display the essential characteristics of mind—purpose and ability to learn by experience. Likewise, there are essential characteristics common to the physiological activity of the central nervous system and the

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* An address delivered at the Otago Philosophical Institute on the 10th October, 1922.

functioning of the mind. I propose, therefore, to lay before you in brief outline the parellelism in the functioning and integration of the body and of the personality, and in doing so I will endeavour to explain how and why that modern method of psychological treatment, psycho-analysis, modifies human behaviour. I will also draw attention to the distinction between psycho-analysis and suggestion.

It will be seen that the action of suggestion, using the term in a broad sense, provides the ideal and gives it strength. Its action is alogical, and often illogical. Psycho-analysis, on the other hand, modifies the afferent and efferent aspects of the mind, cognition and conation, by reason, and modifies its affective aspect by emotional discharge. In a disordered mind psycho-analysis searches for the defects in mental structure, and corrects them by reason. It gives greater efficiency by abolishing internal friction. Suggestion, on the other hand, leaves the defective mechanism unrepaired, but hides it, and, by supplying increased power, enables the mind to get along well enough sometimes. Naturally enough, as might be surmised, psycho-analysis can succeed where suggestion fails, but both methods have their uses.

The integration of an animal organism—the rendering of it an individual unit—is dependent on many factors: there is the mechanical determining structure, the chemical, the circulatory, and so on. These need not concern us to-night. What does concern us, however, is the manner in which the action of the nervous system renders our behaviour one harmonious whole, displaying a consistent purpose; the manner in which the nervous system produces that co-ordination and harmony of movement in various parts, so that, *e.g.*, locomotion, which we may for convenience regard for to-night as the physiological or bodily aim of an animal, is rendered efficient.

REFLEX ACTION.

If the sole of the foot is pricked, the foot is drawn up. This movement occurs with great constancy in response to the above-mentioned stimulus, and obviously serves a useful purpose. It will, under certain circumstances, be capable of production in the same constant, invariable, stereotyped manner even when the spinal cord has been severed and all nervous connection between the legs and the brain cut off, so that no sensory perception of stimuli to the legs is made by the brain, and all power of voluntary movement in them is absent.

Such a movement is termed a true reflex action. It is reflex in the sense that the environment supplies the stimulus, which is conducted by afferent nerves to the spinal cord, from which, after a process of arrangement or correlation there, a stimulus passes by efferent nerves to the limb, and an action results which affects the environment. The reflex action, then, presents, like any other functional mechanism of the nervous system or of the mind, three aspects—the sensory or afferent, the correlative, and the motor or efferent.

It is worth while pausing here to consider the part played by inhibition in the co-ordination of a reflex action.

In a case of strychnine poisoning the body sometimes will respond to a prick of the sole of the foot, not by flexion of the leg, but by a general convulsion in which all the muscles of the body contract simultaneously: no great movement of the parts results, as flexors and extensors contract at the same time. This spread of the stimulus far and wide which occurs under such conditions is normally prevented—*i.e.*, inhibited.

If the left side of the saddle of the dog is scratched by the finger, or bitten by a flea, the left hind leg is raised and performs a scratching movement. If during this process more than one place is scratched the movement becomes more vigorous; but if the right hind foot is hurt, the scratching by the left hind foot is stopped immediately and the right foot raised. Reflexes, then, may, if simultaneously induced, reinforce or inhibit one another. One reflex may furnish, by the response it gives, the stimulus to another, so that a sequence of reflexes may result.

Examples of invariable stereotyped behaviour such as the above reflexes are not common, and are relatively difficult to demonstrate, in the mammal, but can be seen to perfection, as everybody knows, and in highly developed and specialized form, in the behaviour of insects. In them much of their life's behaviour is stereotyped in character, and gives, like the reflex action, an impression of being mechanical or automatic. In mammals, and above all in ourselves, it is difficult to foretell what response will be made to a given stimulus. Behaviour in men exhibits that spontaneity and variability which marks what we designate voluntary movements. Insects, however, do display some intelligence and have some power of modifying their invariable stereotyped action-systems. On the other hand, in mammals, by mutilation of the nervous system so that the control of lower levels by the higher levels is cut off, the existence of systems of stereotyped invariable behaviour is made evident.

The difference, therefore, between the behaviour of insects and of mammals appears to depend on the amount of interference exercised by the highest levels of the central nervous system on the action-systems situated at lower levels, which are designed to produce invariable behaviour. Such action-systems of the mammal as are thus revealed remain primitive compared to those seen in the insect. This, no doubt, is in order that they should be easily modified through interference by higher levels. Reflex actions, such as the drawing up the foot when the sole is pricked, correspond to the invariable action-systems of the insects by which, *e.g.*, the wasp paralyses its prey by deftly directed stings.

We have spoken of the reflex action as an isolated phenomenon, but it never occurs purely as such. If a cow is standing still it is in a state of reflex equilibrium. A stone striking it disturbs that equilibrium, so that the reflex distribution of release of energy which had been determining the attitude of the cow is changed for the time being, and remains changing until another reflex equilibrium is found, and the animal assumes with relative permanence another attitude.

I have, however, forestalled myself here, for I have spoken of this cow as if voluntary movements and reflex actions were identical. There are two speculative views concerning the nature of these two types of activity: One is that all actions are in the beginning voluntary, but that certain of them have become reflexes—*i.e.*, fixed and invariable behaviour with a quasi-mechanical character—as the result of practice either in the life-time of the individual or in the lifetime of his ancestors, who have transmitted them as acquired characters to their descendants. The other theory is the exact opposite—viz., that all actions are in essence reflex, and that so-called voluntary movements are modified reflexes in which the afferent impulse to act, though often obscure, always exists. This difficulty of finding the afferent impulse is due to what an American (Professor Bolt) calls "recession of the stimulus": *e.g.*, a man goes by train; the train is not the stimulus, because he is really going to buy a house, but he is

buying a house for his family to live in, and so on. Neither of these views—that all actions are reflex, or all originally voluntary—is capable of proof at the present time, and an opinion formed as to which is correct depends on mystical or religious belief. Either view may be held as an hypothesis, but it is unnecessary for our present purpose to commit ourselves to either belief. Both views have this in common: an essential identity in the nature of reflex and voluntary actions is recognized. We may therefore, as a matter of physiology, regard any act constituting behaviour in man or animal as reflex.

The action-system is a functional unit of the nervous system. All action-systems are not equally complex, however. The lowest are reflex actions which theoretically would involve but one afferent fibre and two efferent fibres—giving rise to release of energy in one muscle, and inhibiting its release in another. The more complex action-systems include and control the lower, and have centres higher and higher in the central nervous system until we come to the highest of all, the cerebral cortex, which controls voluntary action. The cerebral cortex and brain are built upon the distance receptors—the senses of smell, sight, and hearing. With the information received by these senses they determine what locomotion of the animal shall occur, and control it, though it would appear they do not directly initiate it. What happens is that the activity of one or other action-system is released or inhibited by the fiat of the cerebral cortex. The process can be compared to a man driving a motor-car: he sits in his seat, does nothing to propel the car, but determines its propulsion by releasing or inhibiting the various action-systems in it.

Again you will see why the term "inhibition" occurs in the title of this paper. We are accustomed to consider a motor-car, or a man, in the light of positive result. I wish to stress the fact that a full understanding of the action of the nervous system can be got only by considering the negative aspect of the process—inhibition. This is indeed true of any machine as well, but is most true in an animal organism, which, considered as a machine, shows the acme of adaptability to a variety of purposes.

There is another law to which I would draw your attention. In the mammal the movements produced by the action-systems are relatively crude. They show a primitive tendency to be "all or nothing" responses. The acquisition of delicacy and precision in the amount of movement is dependent on inhibition. The cerebral cortex does not initiate a movement, but uses a crude tool, the action-system, with restraint.

So far I have considered chiefly the motor side; but we have a similar arrangement and similar laws on the sensory side. Increased delicacy of sensory perception, increased discriminative power, is dependent on inhibition or suppression of the crude. Such inhibition on the sensory side occurs at all levels, just as in the case of motor phenomena. Otherwise the lower action-systems would be ineffective. If a sensory nerve be divided the area supplied by it becomes anæsthetic, but if the cut ends are joined the nerve will grow again. The first sensation experienced during recovery is the same whatever form of effective stimulus is applied. A light touch, for instance, is not felt as such, but gives rise to a diffusely localized painful sensation. When recovery has been further advanced the light touch no longer causes pain, but is felt as what it is, and is accurately localized. Increased sensory discrimination has involved suppression of the crude primitive type of sensation, pain. If our hand is being burnt, the pain prevents discrimination of the softness or asperity

of the body which burns it. The crude sensation of pain makes finer sensory discrimination as impossible as it is usually unnecessary.

So also in the brain. If the sensory cells of the cortex are cut off from lower centres the patient, in response to slight stimuli, experiences inordinately extreme and primitive sensations of pain and pleasure. It is only through the inhibition of these sensations and feelings in the lower centres that discriminative perception by the cortex, if I may so speak, is made possible.

When an action-system is acquired in the life of an individual, as when a person learns to walk or to play the piano, niceness and precision are acquired by the inhibition of the crude on the sensory and motor side. On the sensory side there is also combined with inhibition of the crude a heightened sensibility to one form of sensation. Thus the optical nerve-endings in the retina of the eye are insensitive to many crude stimuli, but their sensitiveness to light is heightened.

Let us now pass on to consider the mental structure of man, and in doing so consider to what extent the integrative action of bodily functions by the nervous system provides us with a pattern through which our understanding of the mental structure can be helped.

In the mind we find, corresponding to the action-systems of the nervous system, instincts. In an instinct, as in an action-system, we have three aspects—afferent, correlative, and efferent—but here known as cognitive, affective, and conative. A chicken recognizes insects (cognition), feels presumably some emotion or affect, which accompanies the process of correlation, and strives or conates to peck at the insect and eat it. The chicken is innately endowed with the dispositions to recognize insects, to feel some emotion, and to strive to eat the insect. These three dispositions linked together so as to make a fundamental unity constitute an instinct. Instinctive behaviour may be modified by intelligence on the afferent or efferent, on the cognitive or conative aspect, by reason or intelligence. Thus a chicken pecks at an insect and finds it bitter; henceforward it avoids such insects. The kea discovers that the kidney-fat of lambs is good to eat; thenceforward the sight of a lamb stimulates its instinct for the acquirement of food. In both these cases instinctive activity is modified by intelligence. Increased sensory discrimination has been acquired.

In the chicken the crude impulse to peck at any and every insect is inhibited; in the kea the sensibility to the stimulus of the sight of a lamb is heightened. So also on the conative side, a man learns to replace the angry blow by the use of a revolver. The crude movement of the blow is inhibited, and replaced by a restrained delicately precise movement, carefully aimed.

In the insects, instincts are highly specialized and stereotyped, so that much of the behaviour of these creatures appears in many cases to be quasi-automatic or mechanical. In man, on the other hand, instincts, like bodily structure, are of a primitive and highly generalized type, and capable therefore of great modification by intelligence. Thus it happens that the existence of human instincts is obscured through such modification by intelligence.

Another result of this intelligence which helps to obscure the primary human instincts is the fact that one stimulus may excite several different instincts simultaneously, so that inhibition of one instinct by another may result, as when curiosity is inhibited through fear. On the other hand, one or several instincts may reinforce another one, as when scientific inquiry

derives its stimulus from curiosity, self-assertion, the parental instinct, pugnacity, &c. This calling of several instincts into operation at once by one or more stimuli may lead to conflicts and hesitation—*e.g.*, when fear of punishment conflicts with the desire of the child to steal ginger-snaps from out the cupboard.

It is obviously just as necessary in the interests of man's mind that there should be an integrating factor which will co-ordinate the activities of his instincts, and make them serve a unified purpose, as that the action-systems of the nervous system should be integrated for the purpose of bodily functions.

But let us consider instinct a little further. Reason or intelligence cannot create a primary impulse like that of these primary instincts. Its function is to modify the afferent and efferent aspects of instincts, and is limited to that. But it may be argued that since all these primary instincts are ultimately derived from the fundamental instincts of self-preservation and reproduction, surely they have arisen by the modifying action of reason on them in the lifetime of our ancestors. The answer to this is, I would submit, No. They have arisen by the same process which we see in organic evolution—*i.e.*, variations, and the appearance of logical adaptation which they show to the fundamental aims of man, self-preservation and reproduction—and have been determined not by rational logic, but by what le Bon calls "biological logic."

The use of the word "logic" in more senses than one is unusual, but illuminating. If we are in doubt about the solution of a problem various solutions of it arise in our mind. Thus we may consider whether it is better to use a motor-car, horse and trap, bicycle, or train to make a journey. By the use of reason each possibility that presents itself to our mind is critically considered, and the best method adopted if judgment is sound. This is rational logic.

In the evolution of, say, a duckweed, which appears so logically adapted to its surroundings, instead of thoughts appearing to be destroyed by criticism before being put into practice, we have variations arising—thoughts put into practice and tried out. The failures perish.

For the solution of many problems—*e.g.*, that of aviation—man has followed a process similar to what is seen in the evolution of plants, the method of materialized thought; but in so doing he has combined the exercise of rational with what we might call experimental logic. The evolution of the plant depends purely on biological experiment.

The primary unspecialized instincts of man have arisen through biological not through rational logic. Thus curiosity did not arise as a result of individual trial and error and experience, but must have arisen, as we say, spontaneously, like a variation—*i.e.*, in accordance with the laws of biological logic. Pugnacity arose in the same way; but the creation of the specialized character of the stereotyped instincts of insects may conceivably have depended on intelligence.

The generalized instincts of man, like curiosity and wonder, pugnacity and hate or anger, subjection and submission, self-assertion and elation, parental instinct and love, &c., are manifested in human behaviour as more simple units—wishes. Thus curiosity appears as a wish to look through a crack in the wall, or as a desire to study astronomy. The wish corresponds to the simple reflex action, and as an isolated thing is a hypothetical conception. The satisfaction of an instinct appears to us as an end in itself, and is associated with a feeling of satisfaction.

The tendencies of human instincts are quite amoral. Their satisfaction may occur through actions which we regard as good or bad, praiseworthy and useful or the reverse. Curiosity in the form of prying into the affairs of our neighbour may be good or bad, according as to whether the object is useless inquisitiveness or the detection of crime. Curiosity indulged as a study of botany may be good or bad morally, according as to whether it, *e.g.*, interferes with a man's duty to his family. Self-assertion or self-display is exercised either by a woman who dresses in good taste or by her who makes a vulgar display by overdressing. It is exercised by the man who talks in committee for talking's sake, and by him who talks in order to further the business of the meeting. Every act of man is the exercise of some instinctive capacity. No one could command who had not the instinct of self-assertion; no one could obey who had not the instinct of submission.

Instinctive behaviour may also be modified on any one of its three aspects through the agency of the gregarious instinct. On the cognitive side we have suggestion, by which an idea is acritically accepted. If this occur unwittingly it is called "intuition." On the affective side we have contagion of emotion, which in its action is reciprocal, so that fear begets fear, and the fear begotten in the second person intensifies the fear of the original fearful one. The fear of the originator of the emotion may be simulated. On the conative aspect we have imitation, which may be witting or unwitting. Look in a shop-window, or turn your gaze in one direction, and you know what happens in a crowd. The biological object of these qualities of the human mind has its orgin in the biological need of the herd to secure immediate and unanimous action in circumstances of danger, &c. It is only such action that can save, though at times it may lead to disaster. Hence the justification of the cry "My country, right or wrong," and the force of that appeal. In an emergency we should support our country; if we find our leaders have misled us we should hold them responsible.

THE INTEGRATION OF THE MENTAL LIFE.

When one instinct imperiously demands satisfaction in a man—*e.g.*, self-assertion—it may appear predominantly in the form of a foolish vanity, combined with a lust for power. This instinctive conation, being the dominant motive of the life, may act as the integrating factor of all the other instincts. In such a life, however, some other instincts are apt at times to take control, and by their action may ruin the effectiveness of the self-assertion impulse. In such a life so guided there appears in extreme form that marked inconsistency and lack of subservience to one object which is characteristic of the behaviour of human beings. The integration of our mental life is not so complete as in the case of our bodily activities on the physiological level. In the realm of mental life we are in the plastic region where action-systems are in the making. They are made, as in the case of piano-playing, in the life of the individual, and become what has been called "lapsed intelligence." The crude primitive character of the essential factors in man's mind are presumably retained for the same reason that he retains the primitive type of hand of the reptile—in order to retain adaptability and make advance possible.

The integration of the mental life by the special development of one of the primary instincts is unsatisfactory because it gives rise to instability of character.

It is the nature of man to aim at a sense of unity of personality; for this purpose he is biologically driven to formulate or accept certain mystical or religious beliefs, to have some ideal. It is the ideal which constitutes the integrating factor of the mental life. The ideal, like the instinct, arises arationally, and is governed, like organic variations, by the laws of biological logic. The ideal presents the three aspects of a very psychological or neurological functional unit — the afferent, the correlative, and the efferent—and is capable of modification on the cognitive and conative aspects by intelligence or rational logic, on the affective side by emotional discharge, and on all three aspects through the tendencies characteristic of gregarious animals. The wishes indulged, in thought or act, in infancy give a setting to the mind that has a peculiar permanence, and have a profound influence in determining the precise form which the primary instincts will have as they will appear in acts and wishes later on. Thus in lust, according to the experiences in childhood, curiosity, pugnacity, cruelty, tender emotion, self-assertion, submission, &c., may be more or less marked.

In the very nature of things it is unavoidable that the aims of a man's life are determined arationally. Reason can point out a subsidiary purpose, the attainment of which will lead to a wider purpose. A man may perceive that he must come to Dunedin to attend our University. He may do this in order to attain a wider purpose dictated by reason, but following this process into wider and wider circles of reason we reach the fundamental aims of his life. These cannot be determined by reason, because knowledge is insufficient. There is, as it were, an infinity of purpose, as there is an infinity of time and space. If man is to advance in his social evolution the aim of his life cannot be determined by reason. Reason can only, in the service of his aims, increase his discriminative power, and improve the methods by which he attains his aims and his ability to do so.

The integration of the human life by the ideal is, however, typically imperfect. None of our lives is perfectly integrated. We all, if we are honest, recognize this imperfection in ourselves, and if we do not, others do so for us. At times one or other instinctive conation acquires a power which deflects our behaviour from our ideal. Usually the instinct which is loosed and acts independently of the ideal is not entirely uncontrolled, but is under the sway of some subsidiary ideal. Thus a person otherwise honest may cheat at cards, but be restrained from excessive cheating. Hence arises a splitting of the personality. You have all heard of extreme cases where there has been a sense of double personality, or an alteration of personality.

This feeling of inconsistency in ourselves gives rise to pain and suffering, directly or indirectly. One is tempted to this speculation: Is it possible to make a life a unity of evil, as Richard, Duke of Gloucester, attempted to do in Shakespeare's play? The answer is, No. It therefore follows that despite appearances there is a factor, pain and suffering, which, when we take a broad view, we see driving man in the direction of virtue. Pain is the type of crude primitive sensation. Is, then, organic evolution likewise a flight from pain?

Most people contain the germs of a multiple personality, and various mechanisms are evident in the process by which the discomfort which arises from this fact is lessened, and a sense of a unified personality retained. A common method is to forget all about the irregular conduct; another method is to deny it, or its motive, to oneself.

The ideal cannot directly initiate behaviour, but can do so only in a manner similar to that which is exhibited by the cerebral cortex, which releases or inhibits the activity of the lower action-systems. The ideal releases or inhibits instinctive tendencies, just as the driver of a motor-car releases or inhibits the energies of his motor-car. Just as in the case of bodily integration, so in the mental, increased discrimination, increased refinement of feeling, increased effectiveness and precision in the securing of aims is dependent on inhibition of the crude.

We now return to the so-called primary instincts, such as curiosity, pugnacity, love, and lust. These appear at different ages in man, and there is reason for believing that just as, in the development of the body, the nose and mouth arise from crude processes of flesh which unite to form our handsome features, so the instincts which appear later than birth arise from more primitive instincts or action-systems.

This is, as would be expected, most evident in regard to the latest developed instinct—lust. Instincts are revealed by acts and wishes. The life of the child, with its crude primitive impulses which are without understanding, is, in the life of the individual, forgotten. These memories pass into the unconscious, and are replaced by the fully developed primary instincts, the precise form of which they have taken such an important part in determining. There is inhibition of the memory of the crude, but the setting given to their various instincts in childhood persists: "The child is father to the man." The ideal, compounded to some extent from various instincts, and modified by the gregarious instinct, arises later, and finds itself faced with the task of controlling the primary instincts, through which alone it can work. Its task in some cases is to be likened to the driver of a motor-car where some of the action-systems—*e.g.*, the cooling-system, or the brakes—are out of order. On the plains everything goes well enough, but in times of stress, as, for example, on a steep hill, the car rushes to destruction. If, for example, the instinct of hate and cruelty is overdeveloped, either by heredity or through the influence of environment in childhood, the man, despite his ideal, tends to be cruel; and when stressed by overwork, baffled desire, poison, or disease, may display as monstrous cruelty as he would or did exhibit as a child. Now, however, he is a man, and a more effective agent, and has more mature emotions. The wishes which gave the setting to the instincts in childhood become, like the knowledge acquired in piano-playing, unconscious. This happens during the growth of the ideal.

Not only in the development of the instincts, however, but in the growth and development of higher mental structures such as sentiments, and in the growth of the ideal itself, mental settings are created which pass into the unconscious and constitute mental action-systems on a higher level than primary instinct. It is because the early experiences which have given a certain setting to the instincts or action-systems of the mind at various levels are forgotten, and pass into the unconscious and become incapable of recall by ordinary means, that a man becomes incapable of gaining, through the use of reason, perfection of discriminative power on the cognitive side, and of execution on the conative aspect of his ideal.

Psycho-analysis is a process by which the forgotten experiences are recalled, and the light of reason thrown upon the integration of the life, so that the afferent and efferent aspects of the ideal, of the sentiments and of the instincts, can be modified. There are, of course, limits to the efficacy of the process. There is another mode of action of psycho-

analysis. The affective aspect of mental functional units at any level may be modified by an emotional discharge either in tears of sorrow, or of remorse in some cases, or by symbolic action—*e.g.*, as when a man makes a sudden gesture with his hand to relieve his desire to strike some one. Again, where is the fortunate (or unfortunate) individual who has not found relief of his feelings in confiding his secrets to some one? Tyrant absolute monarchs have felt the need of such relief, and wisdom has led them to confide in unimportant and worthless people, where their confidence was safe. The servant of Midas, possessing the secret that his master had ass's ears, found himself unable to retain it, and confided the information to a hole in the ground by the water's side; and to this day the reeds there repeat the secret they have learned, "Midas has ass's ears." They cannot hold it. We have all heard them tell it on a windy day.

Emotion may be discharged by other means than indulgence in effective conation—*e.g.*, in tears or in symbolic action. It was this cathartic or purgative effect of psycho-analysis that was originally regarded as the cause of cure.

Having placed the action of psycho-analysis from the theoretical point of view, I will now do some little to illustrate some of the mental mechanisms which have been revealed by this study.

Every one now knows that many mental processes occur without the accompaniment of consciousness. We sleep over a problem that calls for solution, and in the morning our mind is made up. This need not be laboured. It is not, however, thoroughly well known that a man's motives may be concealed from himself, but this is well known to occur in the case of jealousy. This is probably one reason why there is a sting for most of us in Bernard Shaw's remark, "When a man is doing something of which he is ashamed he says he is acting on principle." The jealous man has the reputation of his enemy in his hand, and blasts it, while he expresses either ignorance of the significance of his action or declares that the performance of his duty is most painful to him. The onlooker knows the motive behind his action, but finds the jealous man firm for his principle, and unmovable in the fulfilment of his duty, until he has sheeted home to him the existence of his jealousy by recalling to his mind its origin.

What has happened in such a case is that jealousy was aroused in Smith by the success of Thomson in some way. Smith was ashamed of his feelings and impulse, and forgot all about them. He made up his mind that it would make no difference to him, and has been quite friendly to Thomson. The jealous feeling and cruel impulse, however, had not been abolished; they remained in the unconscious, and when occasion offered were indulged by Smith under the guise of a righteous indignation.

A model wife, a pattern of patience, was annoyed one evening by her husband breaking his promise that he would be home at 10 p.m. He arrived at 11 p.m., tired out. She determined to say nothing; but next morning she misread the clock and declared it was 8 a.m., and time to get up, when it was in reality 7 a.m. The husband disliked early rising intensely. The wife's revenge was all the more effective through being carried out unwittingly.

In another instance which I observed the revenge appeared to find merely symbolic satisfaction. A man in my presence made a remark which annoyed his wife, who was drinking tea. She was standing at the

time, and her hand shook a little. She merely made a face and sat down, but in doing so spilt her tea on her dress. I inquired whether the tea had been intended for her delinquent husband, and amid the laughter of all present she pleaded guilty to the impeachment. Next time I met the lady she had on a new frock, so that her revenge perhaps was not wholly symbolic.

Freud, in his psycho-pathology of everyday life, has discussed his doctrine of the unconscious, and illustrated it with many amusing examples. It is one of his, I think, which I will give you: A mean man gave a dance, and provided an execrable supper of tomato sandwiches and weak tea. The guests at supper-time were doing their best to make the conversation go, but the atmosphere was frigid. The host turned the conversation to politics and asked what was thought of (let us say) Mr. Massey's Administration. A guest remarked, "Well, at any rate, one can always rely on his giving one a square meal." Of course, he meant to say "deal"; but his private but not unconscious opinion of his host had been unwittingly revealed.

One could multiply such instances, even from his own experience, without end, and I will pass to more serious cases. A woman in attendance on her invalid mother performs her duty with that heroism which is characteristic of the sex under such conditions. But at times during the long and painful illness the burden is more than flesh and blood can bear; fatigue, the distastefulness of some of her duties, illness, weigh her down, and a wish arises in her that she would like to go to the theatre, get married, die, or see the speedy release of her mother by death. Or, again, a soldier in war comes to the end of his power of endurance, either because he has not much of that quality, any way, or as a result of fatigue and illness. Fear seizes him, and he meditates self-mutilation as a means of escape from his ordeal. There is work, however, to be done by this woman or this soldier, and the temptation is forgotten, but not before a feeling of reproach has manifested itself. The invalid dies or recovers, the war ends, or the soldier gets a "Blighty smack"; and forgetting is now more easy, as a decision seems not longer a matter of vital importance.

Various things may happen. The incidents of the temptation may pass from the consciousness and be incapable of recollection by ordinary means. The feeling of reproach tends to prevent this happening, but this is overcome by the individual concerned transferring this feeling to an indifferent idea. She appears then to the outsider to be reproaching herself for faults which are imaginary or trifling. What is happening, however, is that this indulgence in reproach in this manner is the mechanism which has been hit upon to hide from herself the hate or fear which was inconsistent with the ideal, but had arisen in a time of stress. In other cases the events remain within the call of consciousness, but the reproach is transferred to indifferent ideas, and outwardly the same picture results. Several other mechanisms are known by which the individual may defend herself against the realization of the wrongful wish. The reproach may be turned to an anxiety about health, and a picture of hypochondria results. Having wished others disaster, disaster is dreaded.

What is the reason why a wish—a wicked murderous wish—that her invalid mother's life would end, should arise in the mind of a woman who can be seen to be sacrificing her whole life for her mother? Why should such a wish, tinged with this undesirable emotion, arise at the most unsuitable time? Illness or fatigue, you would say. Yes; but what is

the mental mechanism? This is determined by the motor settings which have been given to the lower action-systems of the mind, and particularly to the primary instincts themselves, during infancy.

Look at the violence of temper of the angry child. What limit is there to her wishes? Her understanding of the significance of her wishes is very imperfect. Her mother is obstructing her will, and she would have this obstacle removed. The most effective manner in which she knows this is accomplished is by death. Shortly afterwards she is expressing her love for mother. The angry incident is forgotten, though a repetition of it probably occurs from time to time. The hate may be more prolonged, and may last for a year or two. The mother becomes an adequate stimulus for both love and hate. It is impossible to organize sentiments towards the mother on such a double basis. For this reason, and with the growth of the ideal, one of these feelings must be suppressed. Usually it is hate that has to go, and an inordinate affection for the mother may develop, leading to the self-sacrificing devotion of the daughter. This reinforcing of the opposite idea—love—is the mechanism the daughter has hit upon by which she succeeds in holding the hate submerged in the unconscious. Such a woman, however, will at times do things for her mother's good, and under the guise of love, which appear to outsiders unreasonable, and which irritate her mother very much. The hysterical element of this love, its martyr-like character, can be removed if the original error is recalled, her infantile hatred expressed, realized, and wept over. This, however, does not usually happen, and the life may later develop the picture I have given above.

What are the conditions which determine this hidden working of forgotten feelings and impulses—which give these things a control over the individual's life? It would appear that if a feeling is stimulated with sufficient intensity, if an impulse arises which has a certain strength, that feeling and that impulse must find an outlet in some way. It is impossible successfully merely to repress or forget without the mental structure suffering damage.

Is it then the case that once a feeling and impulse are sufficiently aroused they must be indulged if we are to have mental health? No! Such a course would not bring mental health, for in the indulgence of this woman's wish for the death of her mother, or of the soldier's desire for self-mutilation, another impulse—that towards the realization of the ideal, or, if not that, then the impulse of love towards the mother—would need to be stifled. If this were done the picture would be different, but the suppressed motive, being of sufficient intensity, would injure the mental structure with as great a certainty.

What, then, is the way out of a dilemma when there are two different antagonistic conations intensely stimulated? They must be integrated. For this purpose it may be necessary to secure some sort of emotional discharge, such as weeping or perhaps merely confession. Then it is possible to give both impulses a discharge in conation, but in such a manner that neither impulse is wholly suppressed. Thus the nursing daughter might come to realize that she could do better for her mother if she did occasionally go to the theatre; but how could she deal with the wish that her mother were dead? This is not so difficult as it would appear. Any son worth his salt looks to the time when he will act as his father does. The son looks forward to the fullness of time to succeeding his father on the farm, and to proving himself a worthy successor. The desire for

the death of the father is the same impulse, but misshapen. Emotional discharge and the work of intelligence, if the original fault is unearthed, will oftentimes permit of a healthy integration in the mind of such conflicting impulses as love and hate towards one object. If, however, the instincts have, through infantile or through youthful experiences, received a certain setting—if at that time there had been a faulty integration—it is oftentimes beyond the power of the individual to correct the error in his mental structure without outside aid from a psycho-analyst.

There is another manner in which such an impulse can be relieved—*i.e.*, in symbolic form. This is known to us all to occur in the impatient gesture of the angry man which does duty for a blow. You have probably all heard of the parson who let off his rage at unruly elders by punching a bolster in the attic. Perhaps you are familiar with the superstition according to which needles passed through a doll will cause the death of the person thought of. This superstition is known to have been practised by a man whose marital relations were unhappy. Such symbolic actions as these are undesirable, but, *e.g.*, the maternal impulse frequently finds symbolic expression in social work of a high order. It is thought, indeed, that many of the highest qualities of normal men are lineal descendants mentally of crude impulses which have been successfully integrated, and are being discharged in symbolic form. The work of the genius is regarded as a successful mighty attempt to overcome objectionable crude impulses or earlier faulty integrations. The eccentricities of genius are in some cases the bursting-forth of the primitive in symbolic form, or in original form.

Superstition is an interesting point. Just now I used it as indicating a wish for a disaster to others, but more commonly it is a dread of disaster to the individual himself. It is a means by which the anxiety which has its origin in reproaches, and would otherwise be free-floating in the mind and disturb the whole life, is packed into, as it were, a corner of it, and certain things, such as cats of a special colour, dogs, open umbrellas in the house, &c., are feared.

There was a man who was superstitious about fox-terriers. The origin of the superstition was an antagonism against his father in youth, which on one occasion was indulged symbolically by his ill-treating a fox-terrier pup.

Any comprehensive idea of the subject that is brief must perforce be chiefly theoretical, and so these illustrations taken at random must suffice, as there is no time for more. The questions raised by modern psychological findings are intensely interesting and of far-reaching importance. He who would learn to appreciate them deeply had needs possess mental stability. His knowledge of psychology must be comprehensive, and his own unconscious mind must be an open book to him. There is a tendency in some quarters to rush wildly to extravagant conclusions and to regard psycho-analysis as the key to the whole problem of human behaviour, just as is done by others when the subject of mental suggestion is considered. The view I have put forward of the mode of action of psycho-analysis is some protection, I think, against such a tendency.

The main subject of this paper is inhibition, and I would in closing thus abruptly again direct your attention to the fact that it is only by considering the action of the nervous system and of the mind systematically, from the point of view of inhibition as well as of release, that any full understanding of them can be obtained.

NATURAL-HISTORY NOTES.

***Sphinx convolvuli* Linn. and *Anosia erripus* Cramer,** by W. W. Smith.

The abnormally late dates on which the imagos of these two species of insects appeared in Taranaki during last season are noteworthy. Hudson gives November and December as being the months in which the perfect insects of *S. convolvuli* appear. The earliest date on which I obtained a specimen previously was the 27th November. In Taranaki they are more numerous in January than during the two preceding months. On the 17th May a little girl attending the Central School, New Plymouth, brought to me a large fresh female specimen of *S. convolvuli* which had been captured on the previous day. The larvae of this beautiful moth feed on the foliage of the kumara *Ipomoea batatas* Poir. The summer and autumn months of 1918–19 were dry and warm, which conditions are favourable to the development of the moth, as they were very plentiful in parts of Taranaki during that period. The autumn and early winter months of this year were also unusually dry, with days of unwonted warmth. On the 19th June Master Sydney Hartnell, of the Central School, showed me a living female of *Anosia erripus* which his uncle caught on a high shrub in his garden two days previously. The specimen is fully developed, but not so brightly coloured as typical specimens generally are. These splendid insects were, no doubt, developed and tempted forth by the abnormally dry and warm conditions of the season.

A Second Specimen of *Idiacanthus niger* Regan from New Zealand, by Gilbert Archey, M.A., Canterbury Museum.

In October of this year Mr. W. O'Connell, of Christchurch, gave to the Canterbury Museum a small fish which he had taken from the stomach of a groper (presumably *Polyprion oxygeneios* Bl. & Sch.) caught at Kaikoura in about 80 fathoms. It has been identified with *Idiacanthus niger* described by Regan* in the *Report of the British Antarctic ("Terra Nova") Expedition*, 1910. Regan's type specimen also came from the stomach of a groper, caught in this case off the North Cape, but at what depth is not stated. If in deep water, it is suggested by Waite† that the groper may have been *Polyprion americanus* Bl. & Sch., occasionally recorded from these waters.

The specimen given to the Canterbury Museum is in fair condition, having lost only parts of the skin and the margins of the fins. It seems desirable, therefore, to record its measurements and other characters, which may be useful in indicating the range of variation of the species.

Six species of *Idiacanthus* have been described, namely: *I. fasciola* Peters, from two small surface specimens from the seas north of New Guinea and Australia; *I. ferox* Günther, from the middle of the north Atlantic, in 2,750 fathoms; *I. antrostomus* Gilbert, from south California, in 603 fathoms; *I. atlanticus* Brauer, collected in the Atlantic by the "Valdivia" Expedition (depth unknown to me); *I. niger* Regan, North

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* Regan, *Ann. Mag. Nat. Hist.*, ser. 8, vol. 13, p. 14, 1914; *British Antarctic ("Terra Nova") Expedition, Fishes, Zool.*, vol. 1, p. 14, pl. x, fig. 2, 1914.

† *Australasian Antarctic Expedition, Fishes*, p. 55, 1916.

Cape, New Zealand; *I. aurora* Waite,* from off Macquarie Island, in 1,450 fathoms.

As suggested by Waite (*ibid.*, p. 55), the fact that *I. niger* and *I. aurora* stand nearest to one another geographically makes further comparisons of these species desirable. I have therefore given in the table below the measurements and proportions of the Kaikoura specimen, together with those of the type of *I. niger* and of *I. aurora*.

——	*I. niger.*	*Kaikoura.*	*I. aurora.*
Branchiostegals	..	XIII	XVI
Dorsal rays..	59	56	60
Anal rays	38	36	37
Vertebrae	..	33–17–31	31–19–32
Head, in length	2/27	2/30	2/28
Snout to ventrals, in length ..	3/8	2/5	2/5
Eye in head	8·5	7·0	5·8
Barbel in head	× 2	× 2·5	× 2·3
Origin of dorsal	Behind ventrals	Behind ventrals	Opposite ventrals.
Origin of anal	Nearer caudal than ventrals	Nearer caudal than ventrals	Midway between caudal and ventrals.
Origin of ventrals	Midway between head and anal	Midway between head and anal	Nearer anal than head.
Total length, in millimetres ..	400	347	425
Lower jaw, length	28	24	27
Barbel, length	58	56	69
Length to caudal	380	337	408
Length to dorsal	170	153	177
Length to ventrals	150	141	177
Length, ventrals to anal ..	120	115	109
Length, origin of anal to caudal	110	110	122

The following characters of the Kaikoura specimen are also noted:—

The branchiostegal membranes have each along their basal portion a row of 14 photophores alternating with the 13 branchiostegals. The photophores of the usual median ventral rows are in number as follows: 40 from the symphysis to the ventrals, 20 from the ventrals to the anal, and 20 from the anal to the base of the caudal; there is also a small photophore just above the maxilla, behind the level of the eye.

The barbel, which is $2\frac{1}{4}$ times as long as the head, arises from the membrane behind the symphysis at one-fourth the length of the mandible, as in *I. aurora*, instead of half-way along, as figured by Regan for *I. niger*. Its distal portion, which is one-third the total length of the barbel, consists of a slight dilation basally, tapering to a fine point distally, and margined by a narrow membrane. A free lobe, projecting from the base of the dilation, terminates distally in a median process, bearing what appears to be a photophore, and guarded by a pair of small membranous lobes.

The lower jaws have each 12 various-sized long sharp teeth and 5 minute ones; the upper jaws have each 14 large and small; there are five on the anterior part of the tongue, one on each side of the vomer, and two anteriorly on each palatine. The tongue has a small papilla at its tip.

Full references to the species of *Idiacanthus*, and plates of *I. niger* and *I. aurora*, are given in the papers by Regan and by Waite referred to above.

* *Australasian Antarctic Expedition*, ser. C, vol. 3, part i, Fishes, p. 53, pl. v, fig. 1, 1916.

REVIEWS AND ABSTRACTS.

Geomorphology of New Zealand: Part I—Systematic: An Introduction to the Study of Land-forms (*N.Z. Board of Science and Art Manual No. 3*), by Professor C. A. Cotton, D.Sc., F.N.Z.Inst., F.G.S., 450 pp., 442 figs. Price—in paper cover, 18s.; bound in cloth, 22s. 6d. This work is obtainable through all booksellers or direct from the Dominion Museum, Wellington, New Zealand.

"The fortunate inhabitants of New Zealand," writes Professor Gregory, "should be geographers by instinct, for New Zealand consists of a collection of geographical models. There is no other land of equal size which is so varied and so complex. It is unique for the combination of the variety of its land-forms, the clearness of their development, and the simplicity of their arrangement." In the decade which has passed since these words appeared, introducing Dr. Marshall's well-known *Geography of New Zealand*, much enthusiastic investigation has been made into the origin of the land-forms of this country, in which Professor Cotton has taken a leading part. The results of his studies and those of his fellow-workers in this field have thrown a flood of light on to the later chapters of the geological history of this Dominion. In the present volume Professor Cotton gives a most lucid account of the principles upon which such inquiries have proceeded, and has illustrated every point by map, diagram, or photograph. Out of the 442 figures, only five are taken directly from lands other than New Zealand; seventy are generalized diagrams; twenty-five are small maps; forty are original and beautifully clear line drawings of scenery; and the remainder are photographs, half of which were taken by the author himself, from all parts of New Zealand, but chosen, wherever possible, from near the principal cities or the more readily accessible parts of the country. The book will thus be invaluable to all senior students or teachers of physical geography in the country, and of absorbing interest to others who, not content merely to admire the beauties of New Zealand scenery, find an added pleasure in seeking to understand their significance.

The reader would do well to commence with the second chapter. Here briefly are described the processes which mould the earth's surface, and the rocky materials on which they work. We then trace in more detail phenomena under normal weather conditions, the decomposition of the rocks, and removal of waste into and down the streams, the development of valleys and flood-plains, and are made to realize the close interrelation of all the features in any region, which becomes, as it were, a living whole. We learn to recognize the departures from the normal series of forms caused when any factor has interrupted the continuance of the process, such as when the land has moved up or down, the climate has changed, or volcanic outbursts have built up new land-masses on the former surface. The treatment follows the general lines laid down by that great geographer Professor W. M. Davis, but the author has collected and woven into the discussion the various new concepts which he has at times added to the science. Each idea is introduced as required with a lucid explanation, made vivid by a clear illustration, and crystallized into a brief explanatory term.

Happily, New Zealand is without deserts, but in parts of the South Island the comparative aridity has had a marked influence on the processes moulding the land-forms, and here, as along the coast-line, the action of the wind is clearly visible. In this section the author makes good use of Dr. Cockayne's researches on the dune areas of New Zealand. Here, as in the preceding action, we see how the disturbing action of the white man, and the rabbit he has introduced, has upset the age-long balance of nature, and has led to the rapid stripping of soil from places where it has been accumulating for centuries.

The features of glaciers and the work accomplished by them find appropriate illustration in the Southern Alps and Fiordland; and we note that the author is of the opinion that the cutting-out of deep troughs such as Lake Wakatipu or Milford Sound finds adequate explanation in the profound glacial modification of the normal river-valleys which had been developed before the glacial period. One might here have welcomed an outline of the alternative explanations that have been offered, and the criteria used in deciding upon the most probable; but doubtless the author felt that an adequate discussion would be out of place in a book of this nature. This is a point which has been much debated, and the question has hardly been closed yet.

A brief account follows of volcanic activity so far as it modifies the form of the earth's surface, and of the special features that result from the erosion of volcanic rocks.

The concluding portion deals with the features of coasts, on which subject the author is a widely recognized authority. The new conceptions which have been introduced as a result of his studies of New Zealand coasts are employed in a general treatment of the problem developed from Gulliver's pioneering work, and running more or less parallel with that of Johnson's recent book. We are shown how to distinguish coasts which have been recently elevated or depressed, and to infer the length of the period that has elapsed since the movement. We see also how these features are simulated by lake-shores; and the book ends almost abruptly with an illustration of part of the wonderful series of shore-lines encircling Lake Rotorua, which indicate the former greater extent of that lake. The absence of further comment on these is a hint of the wealth of material that still remains for investigation, and we await with more interest the second volume of this work, in which Professor Cotton proposes to study regionally the later history of New Zealand as revealed by the land-forms therein.

The reader would do well now to turn to the philosophical introductory chapter, for which at first he may scarcely have been prepared. He can now see what a powerful aid to investigation is the series of definite concepts with which he has been provided, each term or phrase denoting not merely certain typical land-forms, but also explaining their mode of origin, and their relationship with adjacent forms; and he must surely be led to attempt to read for himself the history of his homeland as revealed in its scenery.

A due word of commendation must be given to the book-making. The work is remarkably free from misprints, the illustrations are well chosen and clear, and the index very full.

W. N. B.

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VOL. V. WELLINGTON, MARCH, 1923. NO. 6.

AUSTRALASIAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

Wellington Meeting, January, 1923.

THE sixteenth meeting of the Australasian Association for the Advancement of Science was held in Wellington, opening on the 11th January and closing on the 17th. The meeting was the first to be held in Wellington, and the only meetings previously held in New Zealand were the Christchurch and the Dunedin meetings, in 1891 and 1904 respectively. There were present about four hundred New Zealand members and associates, and about one hundred visitors from Australia. More Australian members would have come but for the uncertainty of the movements of steamers that was incidental to the strike of seamen that had just taken place, and that, it was thought, might extend. The date of opening had been first fixed for the 9th; but a change was made owing to the Sydney boat being delayed. A number of visiting members arriving at the Bluff from Melbourne did not reach Wellington until the second day of the meeting.

On the morning of the 11th January members assembled at Victoria College to register and receive their badges and members' tickets. Committees met and arranged business for the following day. Then followed the civic reception by His Worship the Mayor, Mr. R. A. Wright, M.P., at the Town Hall at noon, and in the afternoon the members were received and entertained by the local Council at the Kelburn Kiosk. In the evening the real business of the meeting commenced at the Town Hall, where the President, Mr. G. H. Knibbs, C.M.G., delivered his presidential address.

Old members of the Association expressed the opinion that the Wellington meeting ranked high both from the point of view of the scientific work done and from that of the provision of opportunities for social intercourse. With regard to the latter, much of the success was undoubtedly due to the work of a very energetic and efficient committee of ladies. The ladies of the Pioneer Club invited the members to a

very pleasant afternoon tea. On an excursion to Waikanae the members were the guests, at Paraparaumu, of Mrs. and Mr. W. H. Field, M.P. The officers of the Biology Division of the Agriculture Department invited members to view a collection of New Zealand flowers, especially alpine flowers—probably the best collection of the kind ever got together; and the pleasure of afternoon tea was found to be added. Several members visited the Milk Depot, at the invitation of the Milk Committee of the City Council. A conversazione was held at Victoria College on the last evening of the meeting, Wednesday, 17th January. This proved a most enjoyable function. The programme included kinematograph views, music, illustrated talks on forestry and water-power, demonstrations of automatic signalling, polariscope, Milne-Shaw seismograph, and useful and noxious insects. The Boys' Institute band was in attendance, and an excellent supper was arranged by a committee of ladies.

The Mueller Memorial Medal was awarded to Mr. J. H. Maiden, I.S.O., Director of the Sydney Botanic Gardens, for researches in botany.

In connection with the meeting a pocket-book entitled "New Zealand Nature Notes," containing short sketches of the geology, botany, zoology, ethnology, and engineering-works of New Zealand, was issued to members.

After the meeting a number of members visited Nelson, where they were the guests of members of the staff of the Cawthron Institute or of other friends, and where several excursions were carried out.

The next meeting will be held in Adelaide in August, 1924. The President of that meeting will be Major-General Sir J. Monash.

OFFICERS OF THE MEETING.

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INAUGURAL ADDRESS.

The incoming President, Mr. G. H. Knibbs, delivered his presidential address in the Town Hall on Thursday evening, 11th January. A large audience of members and others was present. The retiring President, Sir Baldwin Spencer, formally installed Mr. Knibbs. After the address was delivered, a vote of thanks was proposed by the Hon. Sir Francis Bell, and seconded by the Hon. G. M. Thomson, M.L.C.

Mr. Knibbs took as the title of his address—

SCIENCE AND ITS SERVICE TO MAN.

[*Abstract.*]

The role of systematized knowledge, and its application to human needs, have an ever-growing significance; we must create for the rising generation the opportunity of better scientific training than has yet existed. The address went on to indicate primarily the characteristics of the higher elements of science, which served not merely utilitarian purposes—viz., the maintenance of man on the planet—but such a maintenance as enables him to spiritually apperceive and intellectually grasp the beauty, magnificence, and majesty of the whole range of nature—in fact, to make him a student capable of appreciating and solving the most apparently hopeless problems. It is due to the fact that epoch-making conceptions have flashed into the mysterious world of mind, like meteors in a celestial vault, that humanity has been enriched.

In regard to the creative power of science, Mr. Knibbs said that Stieglitz, of Chicago, and Berthelot, of Paris, have insisted that chemistry, interpreted in the wider sense, permeates the whole life of a nation as a vitalizing, productive, and constructive agent. To it we owe the multitude of chemical and pharmaceutical products, the fertilizing agents, the splendid dyes, perfumes, and flavouring substances, the explosives, viscoses, celluloids, xylonites, bakelites, &c., and the metallurgical processes, steels, and alloys, which have cheapened construction and created new possibilities in manufacture.

In achieving knowledge man has had to create accessories by means of which the range of unaided human perception has been enormously extended: thus the ultra-microscope, the large telescope, the X-ray spectograph have opened up new and wonderful vistas in nature knowledge. For example, Plaskett with his 72 in. reflector in Canada's great Astrophysical Observatory discovered that an insignificant star of the sixth magnitude between Betelgeuse and Procyon really consists of two stars revolving round one another in about 14·4 days, one being seventy-five times and the other sixty-three times the mass of our sun, and of a temperature of 16,000° centigrade. This star, 10,000 light-years away, visible to the telescope only as a point of light, is nevertheless revealed by the spectroscope to be what is known as a spectroscopic binary.

The dimensions of atoms, as revealed by calculations based upon compressibility and contraction in chemical combination, as deduced from viscosity measurements, from considerations of atomic structure, and from X-ray spectography, were in extraordinary accordance, and were given in the address. In a series of fifty-four compounds the closest approach to atoms ranged between 1·3 to 4·7 Angstrom units—ten-millionths of a millimetre. To realize this, if a particle of helium were magnified at the same scale which would make a centimetre ($\frac{4}{10}$ in.) the size of the earth it would be about 10 in. in diameter.

The part played by vitamines in dietetics was dealt with at some length, and the fact that it is not sufficient that a food should have the proper protein-fat-carbohydrate content—it must have also the proper vitamines in order that it shall function as a nutritious food. There is in fact a mutual relation between plants and animals in respect of their mutual nutritional needs, as has been shown by the work of Bottomley on auximones.

Research into the endocrine and other ductless glands in human development was then dealt with, special attention being directed to the fact that adrenalin can now be manufactured synthetically. An extract from the posterior lobe of the pituitary gland injected into the circulation reacts on the heart-beat and blood-pressure. The hypertrophy of this gland results in gigantism in early life, and in later life in acromegaly, while less than normal secretion involves obesity, increased tolerance of the carbohydrates, and sexual infantilism. The functions of these glands have been learnt through clinical-pathological observations and through experimental work upon animals.

The need for research was strongly emphasized. It is not sufficient merely to make available the immense stores of existing information; the development of faculty is also a matter of supreme moment. The lavish gifts of Prince Demidoff, Lick, Rogers, Rockefeller, Carnegie, the late Prince of Monaco, and Cawthron were mentioned; also that the British Government has granted a million sterling for industrial research associations, and otherwise nearly four and a half millions sterling for research. Japan has built a National Research Laboratory at a cost of over £300,000, of which the Mikado has contributed £100,000. In Germany the Badische Soda-und-Anilin Fabrik had spent seventeen years and one million sterling in order to produce a satisfactory indigo. At the beginning of the century it was paying annually £600,000. At the outbreak of the war Germany was selling annually £2,500,000 worth of the dye.

PUBLIC LECTURES.

Public lectures were given in the Town Hall concert chamber on four evenings, and were well attended by members and others.

On Friday, 12th January, Sir Baldwin Spencer delivered an address on "The Life of a Stone-age Savage." The lecturer, some thirty years ago, was ceremonially inducted into the mysteries of the totem of the Grub as a full member of the clan. The social customs, religious beliefs, corroborees, songs, and burial customs of some tribes of central and northern Australia were described, and illustrated by means of lantern-slides, cinematograph-films, and phonograph-records. Sir Baldwin Spencer said that the Stone Age of our ancestors in Europe was similar, even to tribal customs, to that of the black aborigines of Australia. In one tribe studied, women prior to marriage, at age fourteen, were not permitted to wear anything; afterwards they might wear a necklace. Widows had to crop their hair and brand their foreheads in token of their widowhood. After relatives died, women were not allowed to speak. They, however, might talk with their fingers. The burial ceremonies were arranged to appease the spirit of the buried person, and showed, by plentiful cutting of oneself and perspirational devotion, that he is being properly mourned for. A remarkable kinematograph view was shown of the scene round the burial-ground of a chief in tall *Eucalyptus* forest, where a series of emblematic dances were performed by some one hundred completely nude adult men. Retribution was sufficient if meted out to the community of the offender. The killing of the father of the murderer was as efficacious as a solvent of righteous anger as the killing of the murderer. Sir Baldwin Spencer saw the departure of a body of natives on such a manner of revenge. They returned with twigs of a certain bush in their hair, and a patch of a certain pigment on their heads, quite satisfied with having killed a relative of the slayer.

On Saturday, 13th January, an address was delivered by Dr. R. J. Tillyard, Chief Biologist at the Cawthron Institute, on "The Control of Insect Pests." The subject dealt with the various methods by which the control of insect pests was attempted. The chief methods described were the biological ones, and striking examples of successes achieved in America were given. The lecture was illustrated throughout by lantern-slides.

On Monday, 15th January, Sir Douglas Mawson delivered a lecture on Antarctica. With the aid of lantern-views and a magnificient series of kinematograph-films Sir Douglas took the audience, in imagination, from Hobart through the stormy Southern Ocean to Macquarie Island and the Antarctic Continent. Life in the south was vividly described. Of special interest was the bird-life, the ways of the penguins causing much amusement.

On Tuesday, 16th January, an address on "The Romance of Hawaii" was delivered by Mr. E. C. Andrews, who dealt with the history of Kamekameha, the Napoleon of the Pacific, and contemporary of Captain Cook; with the peculiar resonance and beauty of the language; the charm of the people; the glow and glamour of the scenery; the geological history of the group; and the comparison with some of the Hawaiian legends of the origin of the group. The lecture was illustrated by a fine series of lantern-slides, many of them beautifully coloured, of the luxuriant vegetation and the rugged scenery of the Hawaiian Islands.

Mr. Andrews made special reference to the forthcoming Pan-Pacific Science Congress to be held in Sydney and Melbourne in August of this

year, dealing with its history and achievements. The aim of the triennial congress is to promote harmonious relations between the nations within the Pacific region. This is expected to be accomplished by the consideration of economic and social problems which are common to all these nations. At the symposia arranged all existing knowledge will be correlated and co-ordinated, and in this way it is expected that such problems as the following will be solved in the near future: Bunchy-top in bananas, yellows in pineapples, sugar-cane pests, rhinoceros-beetle in coconut, malaria, elephantiasis, preservation and administration of native races, protection against earthquakes, forecasting of weather, ocean-charting, and fisheries. To this end 250 leading institutions, including some from Britain, France, and Holland, since they have interests in the Pacific, have been invited to send delegates. Two hundred and fifty eminent scientists concerned with Pan-Pacific problems have also been invited.

EXCURSIONS.

Local excursions to points of interest to geologists, botanists, engineers, and others were arranged by the local Council, and were well patronized, especially by visitors to Wellington.

Through the courtesy of a number of residents of Wellington who lent their cars for the occasion, what proved to be an enjoyable excursion to Wainuiomata Reservoir took place on Saturday afternoon, 13th January. About thirty cars left Bowen Street shortly after 2 p.m. On arriving at the upper reservoir the visitors alighted and walked as far as the western entrance of the tunnel. They then returned to the lower reservoir, where afternoon tea was provided by the Wellington City Corporation. The Mayor, Mr. R. A. Wright, made a short speech of welcome, to which Mr. Knibbs replied. The cars then returned to town, arriving between 6 and 7 p.m.

On the same afternoon Professor C. A. Cotton conducted a party to the summit of Tinakori Hill, where a view was obtained of Wellington and the surrounding district. Features of geological interest, including the Wellington fault-scarp, were pointed out by Professor Cotton. A harbour excursion was arranged for this afternoon, but owing to the high wind it had to be abandoned

On Wednesday afternoon, 17th January, members of the Association were the guests of the Eastbourne Borough Council to a harbour excursion, and of the Wellington Harbour Board to afternoon tea at Eastbourne. The "Duchess" left Queen's Wharf at 2 p.m., and, after cruising round the harbour, landed the party at Rona Bay, whence the guests proceeded to the new pavilion built by the Eastbourne Borough Council. Here afternoon tea was provided, and speeches of welcome were made by Mr. Harkness, Chairman of the Wellington Harbour Board, and Mr. Mather, Mayor of Eastbourne. To these Mr. Knibbs responded. A short walk to the Eastbourne Park was made by some of the members, and the party then returned to town by the "Cobar."

An excursion, of interest mainly to geologists, was conducted by Mr. P. G. Morgan on this same afternoon. The party went to Lyall Bay, walked along the coast to Seatoun, and returned thence to Wellington. The chief feature of interest was the rock and shingle platform raised partly by the earthquake of 1855.

PROCEEDINGS OF THE SECTIONS.

SECTION A.—ASTRONOMY, MATHEMATICS, AND PHYSICS.

Presidential Address: "The Theory of the Polar Front," by Captain E. Kidson.

[*Abstract.*]

During the war the Scandinavians were faced with the problem of maintaining their normal forecasting services without any reports from belligerent countries. In order to compensate as far as possible for this loss of outside information they were driven back on an intensive study of the reports from their own observation stations. As a result they gained a far greater appreciation of the detailed processes of the weather than had ever been attained previously. The most important development from these researches is the theory of the "polar front" in the circulation of the atmosphere, which has resulted already in an enormous improvement in the accuracy of weather-forecasting in Scandinavian countries, and there was no doubt that when its bearing upon Australasian conditions had been fully worked out similar improvements would be possible here also. The general import of the theory was that the weather phenomena of the temperate regions were the results of the interaction of easterly currents of cold air coming from polar regions with the warm, moist, westerly currents which originated in subtropical regions. The cold, easterly polar current in each hemisphere branched out at some distance from the Pole into four spiral arms, between which the warm tropical currents penetrated. On the western side of the cold current the two air masses were thrown together owing to the effect of the rotation of the earth, and an anticyclone, or high-pressure system, was formed. Thus there were formed four moving anticyclones travelling round the earth approximately 90 degrees of longitude apart.

"The Solar Eclipse of 21st September, 1922," by Dr. C. E. Adams.
"Wireless Measurement of Longitude," by Dr. C. E. Adams.
"Intensity of Wireless Signals," by —. Green.
"Investigations of the Upper Winds at Wellington," by W. G. Harwood, Miss E. W. Fenton, and Dr. E. Marsden.
"Cloud Heights from Melbourne Observatory Photographs," by Captain E. Kidson.
"Wind Frequencies in the Upper Air at Melbourne," by Captain E. Kidson.
"Thermal Conductivity of some New Zealand Timbers," by J. C. Lomas and Dr. E. Marsden.
"Viscosity of Sulphur," by Dr. McLeod.
"Measurements of the Penetrating γ Radiation present in the Atmosphere at Apia, Samoa; Wellington, N.Z.; and Mount Ruapehu, N.Z.," by Dr. E. Marsden and W. G. Harwood.
"Investigation of the Winds of the Upper Atmosphere at Apia, Samoa," by Dr. E. Marsden, Professor D. M. Y. Sommerville, and A. Thomson.
"The Emergence of Relativity in Professor Whitehead's Philosophy," by E. V. Miller.

[*Abstract.*]

For many years past there had been much destructive criticism of certain assumptions of science which had reference to time, space, and matter—assumptions which lay at the very foundation of the scientific system of knowledge. Professor Whitehead focused this criticism by showing that in building on a set of concepts such as those mentioned, science was departing from its own peculiar method of attacking the problems of nature—namely, that of placing observation at the basis of all knowledge.

His method of procedure was to apply the observational principle of science consistently throughout the whole field of natural philosophy. "We do not experience such things as matter, time, and space," he said, "we only think them. We experience the ever-varying character of forces—hardness, colour, sound, and so on. Our

system of knowledge, if it is to be truly scientific, must be based on what we experience, not on what we think. Matter, time, and space are details of what we think about our sensory experiences. They belong to the superstructure of knowledge, not to the foundation."

Nothing can therefore really be observed but events and the relation between events. Even an object such as the Great Pyramid was primarily an event. When we contemplated the life of a star from its nebular stage through its giant stage and its varied stages of condensation we rightly regarded the history as a series of events. Compared with one of these events the Great Pyramid appeared and was gone in a flash. We could not really observe objects. We could observe sameness between the characters of various events; and when that sameness was sufficiently stable our sense of the occurrence, being an event, retired into the background of our consciousness, and we replaced it by the intellectual concept we called "object." The progress of nature in the Great Pyramid yesterday so closely resembled the progress of nature therein to-day that we forgot we were observing an event, and thought we were observing an object. In Professor Whitehead's philosophy the relativity theory rested upon a far wider observation-basis than was the case in Einstein's approach to the theory. The latter had to do almost entirely with optical experiments, hypothetical or actual.

"Maps of New Zealand and Adjacent Oceans for Radio-directive Purposes," by W. F. Robinson.

"Radio-active Contents of some New Zealand Rocks and Natural Waters," by M. N. Rogers.

"Shadow Bands observed at Wallal during the Solar Eclipse," by Professor A. D. Ross.

"Photographic Measurement of the Brightness of the Total Solar Eclipse of 21st September, 1922," by Professor A. D. Ross.

"Electro-osmosis in Wood," by A. M. Wright.

SECTION B.—CHEMISTRY.

Presidential Address: "Some Chemical Characteristics of the Australian Vegetation," by H. G. Smith.

[*Abstract.*]

Some of the chemical peculiarities brought to light during investigations of the Australian vegetation appear to be characteristic of this unique flora, and indicate a distinct uniformity in progressive characters, suggesting evolutionary processes as the directing influence in the production of the numerous groups and species which, in the aggregate, go to form the more important genera.

The genus *Eucalyptus* apparently originated in what is at present the western and north-western portions of Australia, and as it spread eastward and experienced varying degrees of soil and climate the conditions demanded by those new locations and climatic changes were met by the responding characteristics of the genus.

Eucalyptus is essentially an oil-producing genus, and already about forty distinct chemical constituents have been isolated and characterized. These include eleven alcohols, nine aldehydes, two phenols, seven esters, five terpenes, one ketone, one sesquiterpene, one paraffin, and also cymene and cineol.

The two main factors controlling the chemical sequence throughout the genus may be stated in the following terms: (1) The same species of *Eucalyptus* has chemical properties of a comparatively constant nature wherever found growing under natural conditions; and (2) each constituent follows the sequence of species in increasing amount until a maximum is reached in one or more of them.

These conditions are not only true for the several oil products, but may also be applied to the astringent exudations, or kinos, produced in varying amounts by all the species. The characteristic features of these exudations are traceable right through the genus, and are particularly noticeable with the two crystalline substances, aromadendrin and eudesmin, found in the older species of the genus. These substances become extinct when the group of "ironbarks" is reached in the sequence of evolution, and are, of course, absent in all the more recent species, such as those belonging to the "stringybarks," "peppermints," "ashes," &c. Eudesmin is a particularly interesting substance, and occurs in the kinos of some species to the extent of 10 per cent.

"The Determination of Nitrogen in Coal," by W. Donovan.
"The Lignite Coals of the South Island of New Zealand," by Professor W. P. Evans.
"An Examination of the New Zealand Pepper-plant (*Drimys axillaris*)," by H. J. Finlay.
"Adsorption and Constitution," by K. M. Griffin.
"The Isomerism of the Crotonic and the B Chlor-crotonic Acids," by F. H. McDowall.
"The Isotope Ratio of a New Zealand Chlorine," by A. D. Monro.
"The Essential Oil of the Manuka," by W. F. Short and C. W. Johnson.
"The Preparation of Cyanacetic Ester," by O. C. Stephens.
"The Valency of Carbon and its Relation to Structure," by Professor F. P. Worley.
"The Kauri-gum Industry of New Zealand," by Professor F. P. Worley.
"The Action of Alkali Cyanides on Gold," by Professor F. P. Worley.
"The Hydrolysis of Potassium Cyanide," by Professor F. P. Worley and R. W. Harman.
"Unsaturation in some Citraconic and Mesaconic Acid Derivatives," by W. A. Joiner.
"South Island Lignites as a Source of Producer-gas," by W. O. R. Gilling and Professor W. P. Evans.
"Tar-oils from South Island Lignitic Coals," by W. O. R. Gilling and Professor W. P. Evans.
"Sulphur as a Factor in Determining the Rank of Lignitic Coals," by Professor W. P. Evans.
"Comparative Study of Three New Zealand Brown Coals as regards Nature of Ash," by L. R. Dunn.
"Leaching by Salt Solutions," by H. O. Askew.
"Preliminary Investigation of a Coal-resin from Central Otago," by L. H. James.
"A Resinous Fossil Wood from Evandale, Mount Somers," by Professor W. P. Evans.
"Note on a Hard Jet-like Coal from Coal Creek Flat," by Professor W. P. Evans and L. R. Dunn.
"Action of various Wax Solvents on Typical Lignitic Coals," by W. O. R. Gilling and Professor W. P. Evans.
"Complete Analyses of the Distribution of Sulphur in Lignitic Coals from the South Island of New Zealand," by Professor W. P Evans.
"The Elimination of Sulphur during Carbonization," by Professor W. P. Evans.
"Low- and Medium-temperature Carbonization of Typical High-sulphur and Low-sulphur Lignitic Coals," by Professor W. P. Evans and J. A. Gilman.
"Some Chemical Components of *Myoporum laetum* (the Ngaio)," by F. H. McDowall.
"A New Method of Measuring Adsorption," by Professor P. W. Robertson and H. C. Richardson.
"A New View of Atomic Structure and the Relationship of the Chemical Elements," by Professor F. P. Worley.
"The Surface Tensions of Aqueous Solutions of certain Aromatic Sulphuric Acids and their Sodium Salts," by Professor F. P. Worley and P. R. Parr.

SUBSECTION PHARMACY.

Presidential Address: "Some Chemical Changes occurring in Pharmaceutical Preparations," by R. C. Cowley.

[*Abstract.*]

Photochemical changes are brought about chiefly by rays from the violet end of the spectrum, the so-called chemically active or actinic rays. Light generally acts as a reducing agent—that is, it is opposed to oxidation. At the same time it has a destructive action on colouring-matter and other substances. Even chlorophyll in living plants has to be protected against the destructive action of light.

It may be laid down as a general rule that heat is decidedly objectionable when applied directly to solutions of organic drugs. Whenever it is necessary to employ heat for the purpose of concentrating pharmaceutical preparations it should be used with great caution. Evaporation under reduced pressure is the ideal method.

Glucosides are particularly susceptible to chemical change—so much so that it is difficult to isolate many of them in a pure condition. Alkaloids are complex basic bodies, mostly of vegetable, sometimes of animal, origin. Quite a number of vegetable alkaloids, such as quinine and strychnine, are very stable, while others undergo chemical change comparatively readily. Some of these changes are particularly noticeable in ordinary pharmaceutical preparations. Enzymes are complex organic substances of a colloid nature. Their action is purely catalytic. They are extremely sensitive to heat and light, and cannot with safety be heated above 60° C. in solution. All are destroyed at 100° C.

Oxidation of metallic compounds from a lower to a higher state of oxidation is well known. Ferrous salts slowly oxidize into ferric salts, especially in solution. The more soluble the iron salt, the more rapidly it oxidizes. Many essential oils undergo oxidation on storing. Fixed oils or fats also change greatly by contact with air and light. Drying oils absorb oxygen from the air and eventually become a varnish.

The cause or causes of rancidity in fats is very obscure. There are several contributing factors. No doubt the presence of nitrogenous bodies from plant and animal tissues have an important bearing on the question. A lard rendered at a high temperature is liable to turn rancid more rapidly than one rendered at a low temperature. Light and air are also contributing factors. Metals in contact with fats appear to accelerate the development of rancidity.

"The Chemistry and Pharmacology of the New Zealand Flora," by R. Gardner.

"The Acidity or Alkalinity Tests of some B.P. Chemicals," by E. I. Rosenblum.

"Liquor Eucalypti Saponatus: Some Experimental Formulae and a Note on its Antiseptic Properties," by B. L. Stanton and A. T. Sissons.

"The Identification of the Solid B.P. Synthetics," by F. T. Parry.

"The Estimation of the More Important Pharmaceutical Enzymes," by C. S. Callaghan.

"A Chemical Change in Liquor Arsenicalis B.P. on Keeping," by C. Delaney.

"The Solubility of Aspirin in Citrate and Acetate Solutions," by F. Tattam.

"The Importance of Standardization of Pharmaceutical Products," by W. H. Attwood and R. E. Shapter.

"Barium Rat-poison," by F. Wright.

"Some Interesting Facts concerning the Venom of the Death-adder (*Aneanthophis antarctica*)," by H. C. Clayton.

SECTION C.—GEOLOGY AND MINERALOGY.

Presidential Address: "The Investigation of the Physical Basis of Primary Production, with Special Reference to South Australia," by L. Keith Ward.

[*Abstract.*]

The general recognition of the need for increasing the productive occupation of such sparsely populated regions as Australia and New Zealand should create a demand

for the contribution of every branch of science towards a solution of the problem of production if that object was to be achieved within a reasonably short period, and without incurring expenditure from which an adequate return could not be obtained. The method of investigation should be the same for all kinds of primary production, whether from the farms, the orchards and gardens, the sheep and cattle stations, the mines, the forests, or the seas. The chief needs in any investigation instituted for this purpose, as part of the machinery of wise statecraft, were thoroughness and systematic recording of results, so that the detailed data were not only obtained but were also available for general use. The method of the geologist, who prepared a geological map of the area he investigated, was a method that could be extended with advantage in fields of inquiry and record within which the use of maps was by no means as general as it should be.

The influence of geology and topography on agricultural production is seen best when the productivity is studied most closely. Broadly speaking, the rugged uplands where the Cambrian and pre-Cambrian rocks make prominent outcrops are non-productive. The lowlands, which occupy the valleys between the ridges of the old rock or constitute the areas submerged in late Tertiary time beneath the sea, are relatively productive. The connection between the geology and the soil-character may be noted in the Mount Gambier district, where volcanic ash has greatly enhanced the productive character of the ground. Much more important than any other single factor in the agricultural production of South Australia is the rainfall. By the study of present agricultural practice in all its branches it will be found that the portion of the State receiving over 10 in. of annual rainfall is responsible for almost all the production.

With regard to the pastoral industry, the statistics of distribution show that large proportions—90·9 per cent. in the case of horses, 73·4 per cent. in the case of cattle, and 82·1 per cent. in the case of sheep—are to be found within the agricultural areas embraced by the surveyed counties. The remaining proportions are distributed over wide areas in those parts of the State less favoured with rainfall than the lands used for agriculture. Soil-character influences the natural edible herbage: for example, the clay loams support the saltbush, while more calcareous soils are relatively poorer through the displacement of saltbush by bluebush; the deeper sandy soils support the edible acacias. But water-supply is indispensable; beyond the areas served by schemes of reticulated water the ground-water becomes the dominant factor of settlement.

The predominant influences governing mineral-production are geological, and the distribution of most productive centres is controlled by the distribution of the rocks of different systems. The mineral veins are practically entirely restricted to the formations older than the Permo-Carboniferous. These old rocks of South Australia therefore constitute the terrain from which most metallic ores are won. But the distribution of the most productive centres is partly controlled by factors other than geological. The climatic factor has adversely affected mineral production in the more arid portions of the State, but against this it may be stated that climatic influences have created the salt industry of South Australia.

"Radiolarian Rocks in Southern Queensland," by Professor H. C. Richards and W. H. Bryan.

"Permo-Carboniferous Volcanic Activity in Southern Queensland," by Professor H. C. Richards and W. H. Bryan.

"The Post-Tertiary History of New Zealand," by Dr. J. Henderson.

"Examination of some of the Tertiary Mollusca claimed as common to New Zealand and Australia," by J. Marwick.

"A Summary of the Characters of the Igneous Rocks of the Whangarei and Bay of Islands Districts, North Auckland," by J. A. Bartrum.

"The Geology of Dunedin," by Professor W. N. Benson.

"The Plutonic and Minor Intrusions of Banks Peninsula," by Professor R. Speight.

"The Igneous Rocks of a (?) Tertiary Conglomerate near Mangapai, Whangarei Harbour, New Zealand," by J. A. Bartrum.

"An Account of the Stratigraphy of the Riverhead-Kaukapakapa District, Waitemata County, Auckland, New Zealand," by J. A. Bartrum.

"The Structural Features of the Australasian Margin," by Professor W. N. Benson.

"A Revision of the New Zealand Tertiary Species of *Limopsis*: Summary of the Chief Points of Interests noted," by H. J. Finlay.
"Albitization and Kindred Phenomena in certain Carboniferous and Permian Lavas of New South Wales" by Dr. W. R. Brown.
"Eruptions of the New Zealand – Tonga Belt," by Dr. J. Allan Thomson.
"The Geology of a Portion of the North Auckland Peninsula," by H. T. Ferrar.
"Notes on the Lindsay Reward Tin-mine," by D. V. Allen.
"Physiographical Types of North Queensland," by Dr. J. V. Danes.
"On the Evidence for Post Lower Carboniferous, Plutonic, and Hypabyssal Intrusions into the Grampian Sandstone of Western Victoria," by Professor E. W. Skeats.
"Notes on the Structural Relationships of the Volcanic Rocks, late Tertiary and Mesozoic Deposits, in New Guinea," by E. R. Stanley.
"Note on some Relations between Australian and New Zealand Tertiary Mollusca," by H. J. Finlay.
"The Occurrence of Andesitic Rocks near Nelson, New Zealand," by W. F. Worley.

SECTION D.—BIOLOGY.

Presidential Address: "The Prickly-pear Problem in Australia," by Professor T. Harvey Johnston.

[*Abstract.*]

Professor Johnston in his address surveyed the spread of the prickly-pear pest in Australia, illustrating his remarks by means of specially prepared maps of New South Wales and Queensland, based on official information, showing the progress of the invasion from 1911 to 1922 in the case of New South Wales, and from 1916 to 1922 in the case of Queensland. The estimated infested area in New South Wales is now approximately 5,000,000 acres, increasing at about 5 per cent. annually, whereas in Queensland the invaded area is probably about 30,000,000 acres, increasing annually at the rate of well over 1,000,000 acres per year. This increase is taking place in spite of all the various means (*e.g.*, poisoning, digging up) employed to control its spread. The region of infestation was mainly limited by the 20 in. and 30 in. lines of annual rainfall, though there were areas with fairly heavy infestation in districts with higher rainfall, and also a region with dense infestation (Blackall, Western Queensland) where the average annual rainfall was about 15 in. It was also pointed out that such regions as are infested are all subject to summer rainfall. Professor Johnston predicted that invasion by the pest would, under natural circumstances, probably be into regions having a summer rainfall, but whose total rainfall averages between 30 in. and 15 in., or even 12 in., annually. If this prediction be true, then the lower limit of the invasion would probably be somewhere along a line from Sydney district to Dubbo and Bourke or Warren, thence more or less northerly in Queensland. A certain amount of infestation would probably occur along the Darling and its tributaries, whose flood-waters have been a very important factor in the spread of the pest.

After reviewing the chief legislative chemical (poisoning) and mechanical means used against the pear menace, the various attempts and suggestions to control it by utilization—*e.g.*, as stock-fodder, as material for paper-pulp, alcohol-production, potash-supplies, dye-production, mucilage, &c.—were surveyed. None of these were likely under present circumstances to lead to the subjugation of the pest. Chemical destruction will pay only in the case of lightly infested areas and in agricultural regions.

The main portion of the address referred to the work with biological agencies, and the results of experiments with various kinds of insects (cactus-bugs, cactus-beetles, cochineal insects, midges, moths, flies, &c.) imported from the United States of America and Argentina, as well as with a number of fungoid organisms and a bacterial disease.

Many highly destructive organisms have now been successfully introduced into Australia, and, having been proved to be restricted to cactaceous plants, are now being bred up at one or other of the Prickly-pear Board's laboratories, with a view to their liberation as soon as the stocks shall have accumulated sufficiently. It was pointed out that most, if not all, of the organisms now being bred up exert their greatest

influence against prickly pear during the warm moist conditions which prevail during summer, and it is just at such a time that the pear is growing most vigorously and is most susceptible to attack. Most of the organisms referred to showed a marked lessening of their destructive power under cold or dry conditions.

It was mentioned also that one kind of wild cochineal insect that had been introduced to Queensland and South Africa had in both places brought about the extermination of one kind of prickly pear, but had failed to attack any other species.

"The Origin and Constitution of the Insect Faunas of Australia and New Zealand," by Dr. R. J. Tillyard.

"The Distribution of some Terrestrial and Fresh-water Australian and New Zealand Amphipoda and Isopoda," by Professor C. Chilton.

[*Abstract.*]

The Amphipoda and Isopoda are groups of small animals with very limited powers of locomotion; they do not hibernate, nor do they lay eggs that can be carried by birds or blown about by wind. Hence the terrestrial and fresh-water forms appear unable to cross even narrow portions of ocean, and the distribution of the members of the two groups is of great importance in considering the methods by which the faunas of New Zealand and Australia became what they are, and the question of former land connections.

From the point of view of distribution they can be grouped in two divisions: (1) Those living in subantarctic lands and presumably distributed from an antarctic source; (2) those that appear to have come to Australia and New Zealand from the north.

To the first group belong several isopods which are represented by similar or identical species in Australia, New Zealand and its subantarctic islands, South America and adjoining islands, South Africa, Kerguelen, and other islands in the South Indian Ocean. Thus species of *Deto* are found in New Zealand, South America, South Africa, Australia, and in the St. Paul Group in the Indian Ocean; species of the genus *Chiltonia* occur in Australia, New Zealand, Tasmania, and South Africa, and are represented by the closely similar genus *Hyalella* in South America; and other forms are similarly distributed.

To the second group belong several amphipods such as *Atyloides*, which has species in New Zealand, the subantarctic islands, in Australia, and in Japan. The common fresh-water amphipod of New Zealand occurs also in Australia, India (Coast of Bengal), and the Philippine Islands; similar species of *Niphargus* in Australia, India, the Philippine Islands, with closely related forms in Japan.

"Some Methods of Preserving, Mounting, and Examining Amphipoda and other Small Crustacea," by Professor C. Chilton.

"The Sound Organs and Songs of New Zealand Cicadidae," by J. G. and I. Myers.

"The Present Position of the Endemic Birds of New Zealand," by J. G. Myers.

"The Position of Birds in the Scale of Evolution," by Professor W. B. Benham.

"The Forest Remnants of the Feilding District," by H. Allan.

"On a Destructive Bacterial Disease of Queensland Fish," by Professor T. Harvey Johnston and L. Hitchcock.

"Notes on New Zealand Fresh-water Fishes," by W. J. Phillipps.

"Remarks on the Respiration and Metabolism of the Tuatara," by Dr. R. R. D. Milligan.

"The Blow-fly Problem in Australia," by Professor T. Harvey Johnston.

"The Recognition of Sheep Maggot-flies and their Allies from Larval and Pupal Characters," by D. Miller.

"Notes on the Development of Amphibola," by Miss Cheyne Farnie.

"Notes on Two Fungal Diseases of the Blue Lupin," by Dr. K. M. Curtis.

"The Wing-coupling Apparatus in *Sabatinca* and other Primitive Genera of Lepidoptera," by A. Philpott.

SECTION E.—GEOGRAPHY AND HISTORY.

Presidential Address: "Geography and Australian National Problems," by Professor Griffith Taylor.

[*Abstract.*]

This address gives a survey of the progress made in the various branches of geography in Australia. Geography is defined as dealing with man's present environment, enabling him to forecast his evolution in the immediate future. The sciences which form the foundation of modern geography are geology, meteorology, astronomy, biology, ethnology, economics, and history.

The population of Australia, with the exception of a few mining settlements, is almost wholly determined by the distribution of rainfall and temperature. The boundary of increasing population in New South Wales is very close to the 15 in. rainfall line. It is thus evident that the inducements for people to settle in the "under 15 in." region are small. In all the States it is shown that there is a general centrifugal movement from the arid lands.

Zones of settlement controlled mainly by climatic factors are defined. Land receiving over 30 in. of rain forms the zone of intensive farming. Here are most of the orchards, dairies, cattle; and, in the north, maize and sugar. But the close farming does not extend west of Cooktown, for the so-called wet belt of the north lacks rain for six months of the year, and so this country has not been tackled by the farmer. The next zone is the intense sheep belt of the south-east. Cattle and dairies occur here, but in much less number. The great wheat belt of the south extends from Geraldton (W.A.) to Roma (Q.). This belt lies in drier country than either the chief cattle or chief sheep country. The less important sheep belt extends from Pilbarra (W.A.) round the south and up to Camooweal (Q.). It is interspersed with cattle-country, especially on the drier and hotter margins, and more or less continuous with it on the north is the less important cattle belt of Australia. There is now left that great central oblong of desert and semi-desert country whose successful occupation constitutes the great geographical problem of Australia. Its limits extend from Broome to Kalgoorlie, thence to Broken Hill, to Camooweal, and back to Broome. The area is about 1,000,000 square miles, and supports just over 1 per cent. of the sheep and about 2 per cent. of the cattle of Australia. This oblong block may be divided into a western useless sand-ridge region and an eastern sparse pastoral country.

The chief physical characters determining the successful location of cotton are temperature, rainfall, and soil. In the United States the cotton belt is well defined, and extends from Texas to North Carolina. The drier limit of the cotton belt is determined by a rainfall of 23 in., but almost the whole is grown with a rainfall exceeding 40 in. a year. The belt lies between the average annual temperature lines of 60° and 70° F. In Australia these conditions occur in a narrow belt which extends along the coast from about Newcastle to Bundaberg, and inland to the eastern margin of the ranges. The centre of cotton-planting in Australia at present is Wowan, near Mount Morgan, which has an annual rainfall of about 33 in. A good deal has been planted in the much drier valleys of Capella (24 in.), Emerald, and elsewhere. But although cotton grows here satisfactorily, those responsible should surely benefit by experience elsewhere and make their chief efforts where the rainfall is well over 30 in.

Discussing future communications, Professor Taylor refers to the proposed overland railway routes from Darwin, one by way of Alice Springs to Adelaide, and the other through Camooweal and Bourke to Sydney. The conclusion is arrived at that in the case of total rainfall, season of rain, reliability of rain, evaporation, heat spells, artesian water, and agricultural possibilities the eastern route has the advantage.

The question of the settlement of Australia by alien races is then discussed by Professor Taylor, who states that the "white Australia" doctrine was a good working policy during the young days of the Commonwealth, but no country in past history has been able to resist the economic pressure of infinitely greater numbers of expanding peoples on its frontiers. Past experience had also shown that the mingling of races of similar ethnical status had produced an improved race.

"Three Periods of Scientific Exploration in Australia," by Dr. J. V. Danes.

"The Isolation of Australia," by Dr. J. V. Danes.

"The Shore Platform of the West Coast near Auckland: its Storm-wave Origin," by J. A. Bartrum.

"The Establishment of a Hurricane Warning Station on Willis Island, 1921–22," by Captain J. K. Davis.
"Future Exploration: the African Quadrant of Antarctica," by Captain J. K. Davis.
"Hunter River Physiography," by C. A. Sussmilch.
"Outline of New Zealand Geography," by Dr. P. Marshall.

Section F.—Ethnography and Anthropology.

Presidential Address: "Some Problems in Mental Anthropology, and the Problem of Civilization," by Captain G. Pitt-Rivers.

[*Abstract.*]

The ethnography of Papua-Melanesian and Micronesian communities of the Western Pacific showed three principal factors operating to ensure social integration: (1) Chieftainship; (2) magic and sorcery; (3) a system of exchange of gifts, partly economic, partly ceremonial and non-economic. Amongst these people tribal law and tribal morality were unwritten, and needed no police or established Church to enforce them. Yet they were far less transgressed than European law and morality. In spite of this fact the whole history of European contact with the natives of the Pacific, especially of recent British administration, has been the story of the wilful destruction of native culture and morality in a vain endeavour to replace it with a culture and morality neither capable of being thoroughly absorbed nor of even proving efficient. The speaker then proceeded to discuss the importance of plurality of wives amongst the Melanesians of New Guinea, and disclosed that in some cases the missionary policy of abolishing this custom would result in not only virtual disappearance of chieftainship, but also of all tribal and communal enterprise, and dislocation of all personal and functional relationships that bind their societies together. Coming to the question of primitive magic and sorcery, Captain Pitt-Rivers said here we were dealing with one of the least understood factors in native life, and were apt to depreciate it and suppress it in the laws which we gave to native peoples. But careful scrutiny of the workings of native social organizations and history of native institutions would reveal the intimacy between the institution of chieftainship and sorcery, and show that the power of the former resided in a great measure in the latter. Our attitude towards native sorcery was often arbitrary and absurd, as native sorcery was often no more unreasonable than many Christian practices.

"The Moa-hunters of Canterbury and Otago," by H. D. Skinner.

[*Abstract.*]

There is conclusive evidence that some of the smaller species of moa were hunted by man, and it is probable that these species were exterminated by him. It may be regarded as certain that the earliest inhabitants of New Zealand hunted the moa, and that it was quickly exterminated. Hence the implements, weapons, &c., found in moa-hunters' camps should throw light on the culture of the earliest inhabitants of New Zealand. The prevailing view for more than a generation has been that the moa-hunters were culturally indistinguishable from the Maoris. Recently a new theory as to the earliest inhabitants of New Zealand has gained general acceptance. It is based on traditional evidence published by T. M. Whatahoro, whose informants stated that the earliest inhabitants of New Zealand were black, and that they were in the lowest stage of culture. These people are usually called Maruiwi, and the Morioris of the Chathams and the Ngatimamoe, an ancient tribe of Canterbury and Otago, are both stated to be of Maruiwi descent. But Moriori evidence is in direct opposition to this.

A study of the objects found in excavating Moa-bone Point Cave, Monck's Cave, and at the mouth of the Shag River leads to the following conclusions: (1) All the known culture-elements of the moa-hunters are characteristically Polynesian—*e.g.*, earth-oven, domestic dog, fish-hooks of the composite and one-piece types, adzes rectilinear in outline and polished; (2) the moa-hunters knew of, and worked, greenstone, which was probably secured by sea; (3) their workmanship seems to indicate greater skill in execution and design than existed among their descendants of a century ago, a decline probably due to isolation and a hard environment; (4) the evidence of Morioris and moa-hunters is in entire harmony, and stands in direct opposition to the Maruiwi cycle of tradition.

"The Racial Diversity of the Polynesian Peoples," by Dr. L. R. Sullivan.

[*Abstract.*]

It is generally held that the Polynesians are a mixed people. The majority of students feel that the mixture took place before migration into Polynesia. Professor Dixon, of Harvard University, from a detailed study and analysis of the available data on Polynesia, proposes four types, which are tentatively identified as Negrito, Melanesian, Caucasian, and Malay. Since then, through the generosity of Bayard Dominick, the Bishop Museum of Honolulu has been able to send expeditions out to make measurements on the living. Studies have been made in Hawaii, Samoa, Tonga, Marquesas, and Rapa. The material was turned over to Dr. Sullivan to get uniformity of analysis and interpretation.

Two types have been isolated, which are tentatively called "Polynesian" and "Indonesian." The Polynesians have light-brown skin-colour, wavy hair, medium hair-development on face and body, moderately long heads with average cephalic index 77 to 78, very high but broad nose, oblique nostrils, nasal bridge elevated above average, chin well developed, eye-fold absent, and tall stature. The Indonesians have a darker skin, wavy hair, scant hair-development on face and body, thicker lips, short heads (average cephalic index 81 to 82), very low broad face, very low and very broad noses, transverse nostrils, low nasal bridge, chin below average, incipient eye-fold, and shorter stature.

Confusion has existed in the use of the term "Indonesian." From the above it will be seen that the Indonesian is the antithesis of the Polynesian in nearly every detail. The Polynesian is strikingly Caucasoid in appearance. At present it is impossible to determine their exact place in the human family. Available data seems to indicate that the Polynesian is intermediate between the Caucasians and Mongols. At present I am inclined to believe they are an offshoot from the primitive Mryoloid stem close to where the Caucasian stock arose. Thus final classification depends on further work.

The two types entered the Pacific at different times, and possibly by different routes. The Polynesians are found in all parts of Polynesia: the Indonesians are not. As to which was first in Polynesia, corroborative evidence from archaeology and ethnology is needed to aid physical anthropology. From the poor representation of skeletal material of the Indonesian element, it seems as if they were late arrivals. It is possible they may have been the first arrivals in certain parts of Polynesia, and that they, instead of the Melanesians, were the short dark precursors of Polynesian tradition.

In addition, there is a Melanesian element in certain parts of Polynesia, as in Tonga, New Zealand, and Easter Island. On the whole, the Melanesian element has been exaggerated. The influence of the Polynesians on Melanesia has been greater than that of the Melanesians on Polynesia.

There is a short-headed type in Tonga, Samoa, Tahiti, Hawaii, and the Marquesas which is not Indonesian. I consider them as a Polynesian type with an artificially flattened occiput.

I thus recognize four types, called "Indonesian," "Melanesian," "Polynesian," and Polynesians with deformed heads. However, much work has still to be done.

"The Independent Evolution of Thought as exemplified by Maori Stringed Games," by Johannes C. Andersen.

"The Canoe-building Tools of the Tasman Bay Maoris," by F. V. Knapp.

"The Geographical Sense of the Maori," by J. Cowan.

"The Maori Gravel Soil of Waimea West, Nelson," by T. Rigg and A. J. Bruce.

"Polynesian Migrations as evidenced by Plant, Place, Colour, Fish, and Metal Names," by F. W. Christian.

"The Evolution of the Maori Art of Weaving," by Dr. P. H. Buck.

"Racial Characteristics and their Relation to Atmospheric Phenomena," by T. Watson.

SECTION G.—SOCIAL AND STATISTICAL SCIENCE.

Presidential Address: "Human Capital," by C. H. Wickens.

[*Abstract.*]

The object of this address was not so much the discussion of the methods of estimating the value of human capital, or the justification for such methods in general,

as the furnishing for Australia of an estimate of human capital for comparison with the estimates which had been called "material capital."

The most recent estimate of the material capital of Australia was that furnished by the Commonwealth Statistician in connection with the war census of 1915. This census gave a total of £1,643,000,000 for the private wealth of Australia as at the 30th June, 1915, while an estimate based on the inventory method as at the same date gave £1,620,000,000. For the purpose of his address, an estimate of the value of the Commonwealth, State, and municipal public assets as at that date had also been made, the total obtained being £517,000,000. So that the total material capital then existing within the borders of Australia might be estimated at £2,137,000,000, or approximately £429 per head of population.

For the purpose of obtaining a value for the human capital of Australia to compare with this material total, an estimate had been made of the average time lost through holidays, sickness, and general unemployment, giving an average effective working-year of forty-eight weeks. Taking this in conjunction with the average adult male wage of £2 15s. 7d. per week for the quarter ended the 30th June, 1915, and the average adult female wage of £1 7s. 3d. per week for the same quarter, gave annual earnings, as at that date, of £133 per adult male and £65 per adult female. The question whether the gross or net earnings should be included was discussed at some length, and the conclusion reached was that, as the whole of the earnings were available to furnish satisfactions to members of the community, the gross results must be regarded as the income of the community, and hence must be used in capitalizing income to determine the value of the human capital.

Dividing the population as at the 30th June, 1915, into the three age-groups of (1) under 15, (2) 15 to 64, and (3) 65 and over, and applying to each sex in each of these groups an average value selected from the results of the various computations, it was estimated that the value of the human capital of Australia as at the 30th June, 1915, aggregated £6,211,000,000, or nearly three times the value of the material wealth, and represented an average value of £1,246 per head in terms of the prices at that date.

"A Brief Survey of Rural Credit in New Zealand," by Professor J. B. Condliffe and H. Belshaw.

[*Abstract.*]

Although, speaking broadly, the joint-stock banks prefer not to finance farmers directly, in the long-run whatever credit is advanced to the farming industries comes from them and is under their control. It is advanced to the farmers through agency companies, loan and finance companies, &c., who take the risks and make their profits out of the connection which they are able to get with the farming community. It is within the power of the banks to raise the rate of interest on overdrafts or otherwise restrict the issue of credit so as to limit the advances which these intermediaries are able to make to the farmers. Similarly, if and when these concerns are in difficulties owing to their advances becoming "frozen" in a time of depression, the difficulties quickly recoil upon the banks. The banking crisis of 1893 was caused in this way,

The present economic position of New Zealand, despite the welcome revival, has in it elements which should cause considerable anxiety. As a result of the post-war boom following upon the prosperous war period, which in turn followed twenty years of almost uninterrupted prosperity, the various credit agencies (and the Government) have been so free in their financing of farmers that the chief industries of the Dominion are in many cases seriously overcapitalized. In view of these facts, and especially since it is clear that the rural industries are suffering not so much from a shortage of credit at the moment as from unsound finance resulting from too much credit in the immediate past, no economist can view with equanimity schemes which offer even a danger of further inflation of credit. The solution of the Dominion's economic difficulties will not be found in a further era of cheap credit based either on borrowing or internal inflation. The scheme for rural credit associations is admirable within limits, but it can do little or nothing to assist the present difficulties. Much the same may be said of the proposal for a State bank. If such schemes are used to provide more liberal credit facilities in an endeavour to evade recognition of the plain facts of the present situation the result will be disastrous.

"Economic Fisheries Research in Relation to the World's Food Resources," by W. J. Phillipps and E. P. Neale.

"The Economic Revolution in the Pacific," by Dr. G. H. Scholefield.

"A Note on the Scope and Uses of the Social Sciences," by Professor J. Hight.
"Some Aspects of New Zealand War Finance," by J. M. Tait.
"The Effects of Compulsory Arbitration on the Clothing Industry in New Zealand," by A. Munro.
"A Short Method of Computing the Arithmetic Mean of a Grouped Frequency Distribution," by E. P. Neale.
"The Trade Depression in Australia in relation to Economic Thought," by Professor D. B. Copland.
"An Experiment in Copartnership," by W. H. Valder.
"The Kauri-gum Industry," by R. W. Firth.
"The Sociological Portent of the Binet Test," by K. B. Murray.

SECTION H.—ENGINEERING AND ARCHITECTURE.

Presidential Address: "The Testing of Materials used in Engineering and Building Construction," by Professor W. H. Warren.

[*Abstract.*]

The testing of materials is recognized in all civilized communities. It is necessary to know the physical properties of the materials used, such as the tensile, compressive, and shearing strength, also the elasticity, ductility, hardness, and the rate of expansion by heat. The usual practice in expressing the results of tests of materials is to state the number of pounds or tons of the load applied divided by the original area in square inches.

It is considered that ordinary static tests, such as the tension tests on standard bars, or the cold-bending test, do not reveal the capacity of the material to resist shocks. In rails, axles, tires, draw-bars, armour plates, moving parts of machinery, and engines the stresses are all more or less suddenly applied. Impact tests reveal the brittleness of the material, or its tendency to fail by suddenly applied loads. Resilience is a function which is the reverse of brittleness, and expresses definitely the resistance to impact. It represents two factors, one of which is the elongations and the other the stresses producing them. A metal which shows a fair resilience will always give a fair elongation in static tension; but the converse is not true, as will be shown by comparing the results of tension tests and impact tests of a certain steel used for the manufacture of high-explosive shells.

The most important method of making impact tests is by the blow of a hammer, whether falling vertically or swinging as a pendulum on bars notched in a special manner. The effect of the notch is most decided in bringing out the properties which we call brittleness or want of resilience. Investigations now in progress were directed towards the standardization of impact tests so that they might be introduced safely in specifications of materials for any purpose whatsoever.

"Train Resistance on the 3ft. 6 in. Gauge," by S. H. Jenkinson.
"Secondary Stresses in Steel-pipe Lines," by R. Roberts.
"Stresses in Continuous Beams and Rigid Frames," by W. S. Gray.
"Hydro-electric Power in New Zealand," by L. Birks.
"Steel Towers for Electric-power Transmission-lines," by L. Birks.
"Electric Storage-battery Traction," by L. Birks.
"Railway Transition Curves," by Professor D. M. Y. Sommerville.
"The Development of Automatic Signalling on the New Zealand Government Railways," by G. W. Wyles.

SECTION I.—SANITARY SCIENCE AND HYGIENE.

Presidential Address: "Recent Progress in Child Hygiene in New South Wales," by Dr. Harvey Sutton.

[*Abstract.*]

The health-control of childhood was now rapidly assuming a position second to none in the whole range of public health. New Zealand undoubtedly led the

world in infant care and management. Measles, whooping-cough, and scarlet fever, although still serious dangers to child-life between one and five years, were nothing like the death-dealing menaces of 1840 to 1875. Scarlet fever in particular had been stripped of its terrors. With regard to the question of malnutrition, the most important feature was unsuitable food. Modern commercial progress, especially in canning and tinning food, and urban overcrowding had led in recent years to a remarkable sophistication of our dietary. The fresh foods were steadily occupying a less adequate position. Milk, fresh meat, fresh vegetables, and butter were poorly supplied, especially to children, who received the same diet as the adults—namely, stews, dripping, tea, bread and jam, salted meat, and fish. Yet in the growing-period the human organism needed these vitamines, which stimulated growth and were useful to the adult but essential to the child. Certain children, living under similar conditions of diet, housing, &c., nevertheless were examples of malnutrition. Many cases occurred among the rich as well as the poor, nor was it all ignorance as to suitable diet. Inherited family tendencies, nervous temperament, &c., deserved attention. From early infancy dated probably the most important background of all. Rickets, so common in mild degrees (20 per cent. or more), caused a large proportion of school cases of malnutrition. The tendency of this disease was to improve, provided the correct diet was available to make up for the losses by early artificial feeding with patent foods. Fresh milk, fresh fruit, and fresh vegetables were our sheet-anchors. Exercise and sunshine helped.

"Education as a Factor in Venereal Disease," by Dr. E. Sydney Morris.

[*Abstract.*]

Legislation, in my opinion, is really a subsidiary factor in the control of venereal disease. The good effects issuing from the law are due more to the consequent public education and facilities for treatment, which do not require legislation, rather than to any inherent virtue in the law itself.

The anonymous notification of cases, which places the primary responsibility in the hands of the medical profession, is unsatisfactory, whilst the majority of medical men find the responsibility of keeping records and submitting reports of cases extremely irksome, and for this and other reasons decline to treat this class of patient. Further, the practitioner who carries out the law is very often subjected to much unpleasantness for sending a patient's name to the Health authorities on account of his having failed to continue treatment.

The defects of legislative control must be realized in order to discover better methods, with richer prospects, for solving the problem. The most important factor is, in my opinion, an educational campaign, and the chief reason for this is that I am convinced the prevalence of venereal disease in Australia is directly proportional to the sexual promiscuity prevalent in the community. This promiscuity applies to both sexes, and is not confined to the professional prostitute and her clientele. The clandestine or "amateur" prostitute is filling the position formerly supposed to be occupied by her professional sister. The extent of this promiscuity can be partly gauged from statistics relating to illegitimate births and first births (after marriage) under nine months, which for the period 1909 to 1920 comprise over 54 per cent. of the total births in the Commonwealth of Australia. If the amount of clandestine illicit intercourse over and above that represented by these statistics were known there is little doubt that the result would be astounding.

In advocating an educational campaign I am under no illusions as to its being the panacea of all our ills, nor do I anticipate abstract moral teaching to all and sundry. What we can do, however, is to enlighten the adults regarding the biological phenomena of the diseases, the causes underlying their dissemination, their dire results in the individual and the race, and, above all, the necessity for the effective instruction of boys and girls, young men and young women, so that they will be protected from eating the bitter fruit of remorse, if not of despair.

"Industrial Hygiene in Australia," by Dr. D. G. Robertson.

"The Rat and Flea Problem in the Prevention of Plague," by Dr. J. S. Purdy.

"Notes on Ropy Bread," by F. L. Armitage.

"Notes on Water-supplies," by F. L. Armitage.

"Preventive Medicine and Hygiene in the Tropical Territories under Australian Control," by Dr. R. W. Cilento.

"Food Value of Fish," by Professor J. M. Malcolm.

SECTION J.—MENTAL SCIENCE AND EDUCATION.

Presidential Address: "The New Psychology and the School," by J. A. Johnson.

[*Abstract.*]

The changes in the world's outlook to-day on the meaning of education, on the function of the school in the life of the community, on the methods of teaching, on administration and control, made it imperative that we should review the situation and try to forecast the future. Really a great educational evolution was taking place, but we seemed too near the changes to interpret its meaning. We could say, indeed, that the old stereotyped system was doomed; new weapons were required to meet new contingencies, and these must be forged in the schools of to-day. It was hopeful to find that the professional man was welcoming the changes, and was prepared to play his part in the call for reconstruction. New situations were arising, calling for deeper insight into the needs of the age and the means to be employed to help the coming generation to cope with the changing environment. The making of good citizens meant more than was implied in the term "general culture." The idea was now being pressed home that the best results in education flowed from individual freedom along the path of self-realization. The repressive methods of the old discipline were now considered educationally bad. Training for good citizenship implied an early association with activities likely to be similar to those in the adult relations, and schools, as at present constituted, seemed to offer few opportunities for developing corporate life. The centre of interest had thus moved from the individual to the community; demand was made for social service rather than for individual advancement. The aim was to lay the foundation of intelligent citizenship tending to a better social order.

"The Human Energy-rhythm throughout the Year," by Dr. A. B. Fitt.

[*Abstract.*]

This is a study of the variations in human activities throughout the months of the year. The first portion is an analysis of seasonal variations in growth and development obtained through presenting to 355 boys and girls of a Melbourne State primary school each month tests for memory and for concentration of attention (cancellation test) as well as by taking at the same time careful records of height and weight. The next portion is an analysis of seasonal variations in suicide, conception, death, and disease obtained from the official records for about eight years for the Commonwealth of Australia and for the State of Victoria.

The first group showed a strong tendency for weight to increase most rapidly in the first half-year from February to July—more rapidly at the beginning of this period and gradually decreasing in advance towards the close. There is a distinct break or crisis in physical development at July–August, height-increase now becoming particularly dominant, and being the chief feature on the physical side in the second half-year, from about July to January. Corresponding to strong weight-increase in the first half-year the mental functions of memory and attention are high, and they fall suddenly at the July–August crisis. Although they rise somewhat in the second half-year, the work done is, on the average, much below that of the first half. Study of speed and accuracy figures in the concentration test shows strong evidence of mental instability at the July–August crisis. The energy-balance of the mental and physical functions shows fair agreement between weight-activity and the mental functions, but considerable contrariety between height-activity and these three. Thus height-activity greatly dominates the energy-balance of the year, the change from weight- to height-activity at the crisis being associated with the mental instability. Alongside this general kind of energy-balance, which shows up for all age-groups, one sees special developmental variations for each age, which, rather than disturbing the general tendency, give fuller meaning to it.

The second group of variations showed strong analogies to the first. The suicide and conception curves were very similar, showing a low level for the first period from February to July–August, and a high level for the period August–January, showing marked rise round about the crisis. Conception-increase, being increase in the activity of the sex-cells, corresponds to the above height-increase, which is increase in the activity of the body-cells, which are biologically descendants of the sex-cells. Suicide-increase contains the same basal factor as was shown by the concentration curves—viz., increase in instability for the second half-year (August–January). Death-increase and disease-increase show greater activity for the second portion of the year, the maximum point coming at the year's crisis.

"The Relationship between the Mental and Physical Development in School-children," by Dr. McIlwraith.
"Sociology and Mental Science in Relation to National Education," by Professor D. R. White.
"Studies of Attention, especially the Development of Concentration," by Dr. A. B. Fitt.
"On the Genetic Relation of Instinct and Intelligence," by R. F. Fortune.

Section K.—Agriculture.

Presidential Address: "Factors Influencing the Water Requirements of Farm Crops under Australian Conditions," by A. E. V. Richardson.

[*Abstract.*]

The address dealt with the results of six years' investigations conducted in Victoria to determine the water requirements of farm crops and to discover the factors which affect the quantity of water used. The water requirements of crops were not constant, but were found to fluctuate from season to season. The composite average winter rainfall during the growing-period of the wheat crop in Victoria and South Australia was found to be practically identical—namely, 11½ in. Assuming the extra water conserved by fallowing would balance the losses of water by evaporation from the soil, the rainfall was sufficient to produce 40 bushels per acre in each State. Less than one-third of this amount actually was being obtained. While with moderate rainfall wheat could yield 3½ bushels for every inch of rain received during the growing-period of the crop, the Victorian wheat-grower, as a whole, had obtained during the last ten years 1·1 bushels for every inch of rain. On the other hand, the whole Wimmera district during the last four years reaped 1·75 bushels for every inch, whilst on the Longerenong College Farm and the prize-winning farms in the Nhill Farm competition an average of 3½ bushels actually had been obtained for every inch of winter rain received.

The investigations showed that some varieties of wheat, particularly Federation and Mandilla King, produce more grain than other varieties for a given amount of rainfall. It was found that varieties with a high percentage of grain to straw were the types which utilized rainfall most economically. Mr. Richardson considers this fact to be of practical importance, as it suggests the possibility of breeding varieties even better fitted to arid conditions than those already in cultivation. The application of fertilizers was found to produce a marked lowering in the water requirements of wheat. This was noticeable with all types of soil, but was most marked with poor soils. The results of the study of the water requirements of cereal crops led him to contend that the rainfall of the wheat belt of Australia is sufficient to produce an average yield at least double that previously obtained.

"Relation of Biological Specialization in the Taxonomy of the Grass Rusts," by G. H. Cunningham.
"Some Economic Facts relating to the Use of Horses and Tractors on the Farm," by F. E. Place.
"Irrigation, Cotton-growing, and Soil Surveys in Europe," by H. T. Ferrar.
"The Utilization of Pumice Soils," by F. C. Rollett.
"Plant Introduction and Improvement," by F. C. Rollett.
"Forest-products Research and its Relationship to the Progress of Forestry in New Zealand," by A. R. Entrican.
"Some Ecological Considerations of New Zealand Grassland," by A. H. Cockayne and E. B. Levy.
"Some Cosmopolitan Insect Problems," by W. W. Froggart.
"Some Aspects of Agricultural Education in Secondary Schools," by E. Breakwell.
"Irrigation Expansion in Australia," by A. V. Lyon.
"The Sheep Maggot-fly Problem in New Zealand," by D. Miller.
"Forest Entomology in New Zealand," by D. Miller.
"Some Recent Views on the Liming of Soils," by H. Wenholtz.

"Fixation of Phosphoric Acid by Victorian Soils," by P. Rankin Scott and W. C. Robertson.
"Black Spot on Frozen Meat," by A. M. Wright.
"The Deterioration of Edible Fats," by A. M. Wright and Miss J. F. Bevis.
"Moutere Hills Soil and its Improvement for Orchard and Agricultural Purposes," by T. Rigg.
"The Value of B. Dyer's Citric-acid Method for Determining the Need of Specific Applications of Mineral Fertilizers for Nelson Soils," by T. Rigg.
"Heredity in Stock-breeding," by J. S. McFadzean.
"The Progress of Forestry in New Zealand," by L. MacIntosh Ellis.
"Futility of Netting and Poisoning Rabbits," by Coleman Phillips.

SECTION L.—VETERINARY SCIENCE.

Presidential Address: "The Prevention of the Spread of Stock-disease," by Professor H. A. Woodruff.

[*Abstract.*]

Before the advent of a veterinary State sanitary service it was not surprising that contagious diseases of animals should have spread from country to country. This period of inability to control the spread of diseases coincided with a very natural desire on the part of colonists in different parts of the Empire to import high-class pedigree stock from Great Britain in order to establish purebred studs and to improve stock generally. Thus the chances of introducing into Australia and New Zealand the prevailing animal-diseases from Europe were considerable, and it is probably owing mainly to the length of the sea voyage that comparatively few of the animal scourges found their way in. On this point it has to be remembered that races of animals which have for many generations been free from any particular contagion are, generally speaking, in a highly susceptible condition should the chances of infection ever occur.

The following propositions are to be considered in a policy for controlling the spread of stock-diseases: The chances of the importation of infection are numerous; the interests involved are economically very important; the necessity for pedigree-stock exchange between the various States is also extremely important; the modern scientific methods for the detection of disease-infection are much greater than a generation ago; methods, regulations, prohibitions, and exemptions must be continually revised.

The methods available for the exclusion of infection from a foreign source are—(1) The prohibition of the importation of live animals from any country where contagious disease of animals exists; (2) the prohibition of entry of animal products, such as hides, hoofs, horns, bones, wool, &c., either absolute or after efficient sterilization; (3) identification of disease by biological tests (the most commonly applied is the tuberculin test); (4) quarantine at the port of entry (this is a valuable measure in the cases of diseases with a short incubation period); (5) veterinary inspection at the port of entry is an essential precaution; (6) other methods are the production of a certificate giving the history of the animals from the date of birth, and the practice of detaining animals in a buffer State for a definite period.

"Toxic Bulbar Paralysis in Horses and Cattle (Botulism and Parabotulism)," by Dr. H. R. Seddon.
"Contagious Bovine Mastitis," by Dr. H. A. Reid.
"Some Digestive Troubles in Cattle," by W. C. Barry.
"Histories of some Atypical Cases of Parturient Apoplexy," by T. A. Blake.
"Which is the Most Humane Method of Slaughtering Stock?" by W. C. Quinnell.
"Studies in Bovine Pleuro-pneumonia," by Dr. G. G. Heslop.
"Contagious Granular Vaginitis," by E. C. Howard.

NOTES ON THE OCCURRENCE OF THE LIZARD IN MAORI CARVINGS,

And various Myths and Superstitions connected with Lizards.

By Elsdon Best, Dominion Museum.

With Illustrations by J. McDonald.

Those who have made any study of Maori carved work are acquainted with the fact that one of its remarkable features is its lack of natural forms. If ever, in evolving his decorative art, the Maori sought inspiration in nature, then such borrowings have been so conventionalized as to lose resemblance to the originals. Thus in his carved, painted, and woven designs we recognize but few natural objects. His delineations are in but few cases derived from the flora or fauna of the isles he dwelt in. Few animals are depicted in native carving; the carved forms of birds so prevalent in Melanesian carvings are here practically unknown, although a strong Melanesian element obtains in the Maori. At the Chatham Islands we find that bird forms were carved on projecting timbers at the prows of their rude canoes, as was common in parts of the New Hebrides. These representations were never seen on the vessels of the Maori.

Early writers mention having seen a design in the form of a fern-frond tattooed on a man's back, but this may have been due to European influence; it was certainly not a pre-European custom. Others, again, have asserted that the scroll in native decorative designs was copied from unexpanded fronds, as of the *mamaku* tree-fern. But the scroll has been a very widespread feature in barbaric art. Even the double scroll has a wide range. In view of the fact that Polynesian decorative art is essentially rectilinear, it would appear probable that the familiar curvilinear designs of local art were introduced from Melanesia, where similar ones were employed. At the present time one sees such natural objects as trees depicted in native-house paintings, and even men are so seen, but this is a very modern usage. Curvilinear designs, closely resembling local forms, are met with in New Guinea.

In turning from the flora of these isles to its fauna we observe a somewhat similar paucity of illustrations in Maori art. We do, however, meet with a few delineations of animals, but in one case only is any creature so depicted as to faithfully resemble the original: that exception is the lizard. Of animal representations more or less conventionalized, we note the *pakake* (whale), the *manaia*, and the *marakihau*. The latter is said to represent some sea creature, and is depicted in carvings as possessing a human body and a long outthrust tongue. In native myth the *marakihau* is credited with the powers of a monster, for it is said to destroy canoes and to swallow hapless mariners by means of swallowing them through its *ngongo*, or tube-like tongue. Possibly the old Maori sea-rovers encountered such creatures as the sea-elephant in their rovings, and so the *marakihau* finds a place in popular story. The fact of its being represented with a human form in carvings may be due to the fact that it is said to resemble a man in form. Those I have seen, however, in house-carvings represented ancestors who

are said to have been transformed into *marakihau* after death, such as Te Tahi-o-te-rangi, of the Ngati-Awa Tribe, of Whakatane.

Of the *manaia* many things have been written, and it seems to have been confused with the lizard, possibly because the name also denoted a lizard. I cannot, however, quite accept the view that the *manaia* of Maori carving represents the lizard. The peculiar design of the double *manaia*, in which two bird-headed figures of strange form appear one on either side of a central human figure, is also found in Melanesian carvings. In both cases the *manaia* have their beaks touching or in close proximity to the head of the human figure. Now, this is a symbolical design that carries us back to Java and India. It is the old, old Indian design showing Vishnu flanked by the two Garudas, the beings representing Good and Evil. These endeavour to influence Vishnu, but in the end Good prevails over Evil. It appears to me probable that many of the interesting institutions, rites, beliefs, &c., of the Polynesian race originated in Asia, and have been carried across the wide seas in the course of many centuries. These flanking figures referred to certainly bear no resemblance to lizards. On the contrary, the lizard is the only animal depicted in Maori carvings that is not distorted or conventionalized, but appears as a good rendering of the original. Even the human figure is, as a rule, distorted in the most grotesque manner. Assuredly the Maori did not endeavour in these designs to faithfully represent the form of man.

To right.—Lizard grasped in the hand of a carved figure as though it was to be eaten.

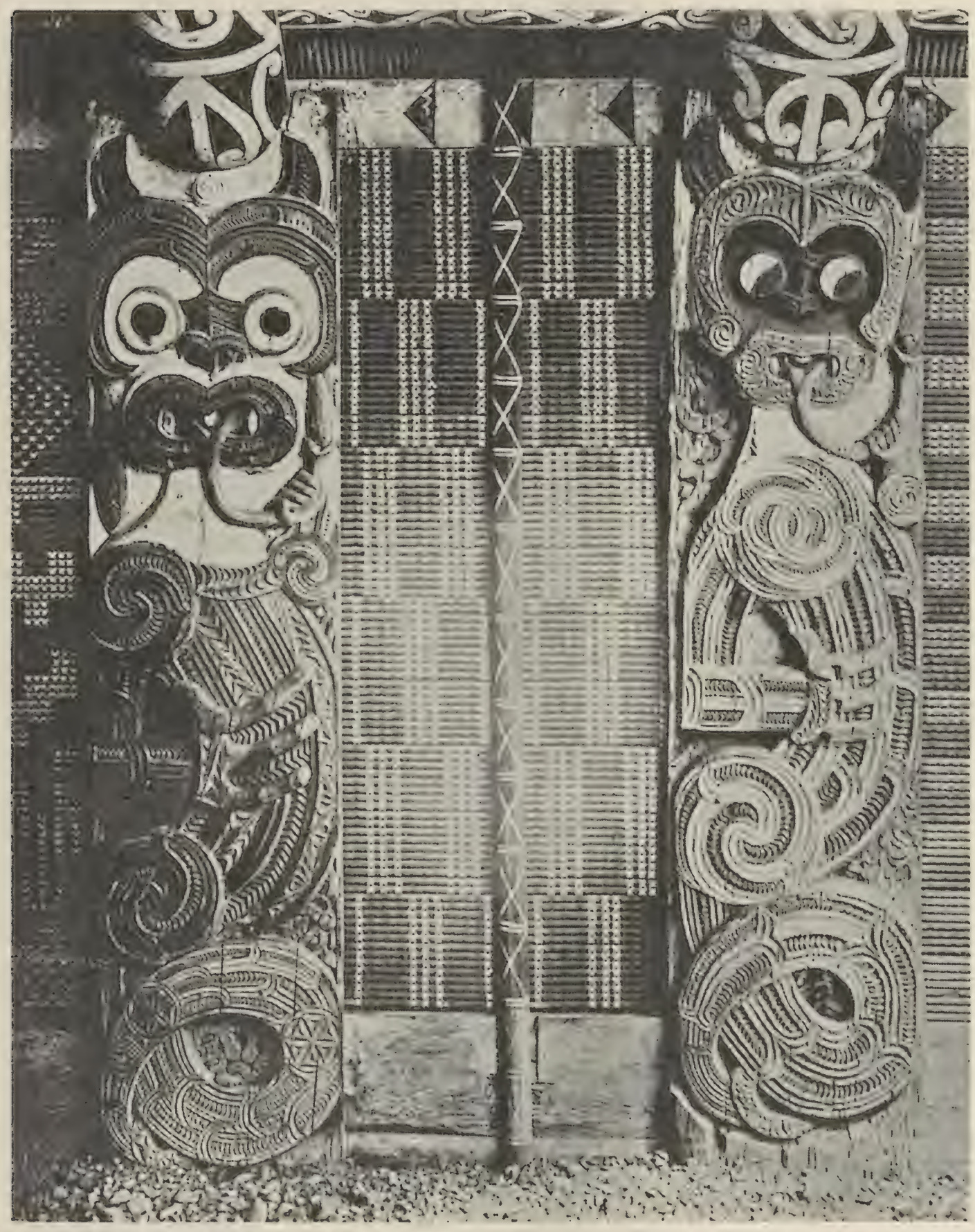
To left.—Grotesque semi-human form: an ancient and peculiarly interesting design.

The lizard is frequently met with in Maori carving, and native beliefs connected with it are of some interest when compared with those of other

peoples of far-off regions. It is also met with in the carved work of Polynesia and Melanesia. Polack, a sojourner in New Zealand in the "thirties" of last century, remarked of native carvings that, "among other favourite subjects, lizards are continually portrayed." Concerning a native house at Ohinemutu, Hochstetter wrote: "The gable figure with the lizard having six feet and two heads is very remarkable; at no other place in New Zealand have I seen a similar representation." In Maori lore Moko-hiku-waru, which may be rendered as "Eight-tailed Lizard," is a name connected with lizards. It may represent a personification, a tutelary being, or one of those beings termed *matua* (parent) by the Maori, who are viewed as creative beings. At Mangaia Island we again encounter this myth concerning an eight-tailed lizard, and it is also credited with the possession of eight heads at that isle. Tu-tangata-kino is another such name connected with lizards. Earle, an early sojourner in New Zealand, wrote of native wood-carving: "One of their favourite subjects is a lizard taking hold of the top of a man's head, their tradition being that that was the origin of man." This is a reference to the *manaia* referred to above; but the statement as to its being the origin of man is not borne out by our present-day knowledge. Fenton, in his *Suggestions for a History of the Maori People*, tells us that "The image of the large lizard placed on one of the *marae* at Tahiti, and the long row of lizards still to be seen in Pokiha's carved house at Maketu, and, in fact, in every New Zealand *pa*, are simply memories of the terrible crocodiles which were the source of perpetual danger, and the occasion of heroic exploits, in the lands from which their forefathers

To right.—Grotesque carved figure possessing a curiously snake-like body.

came." This may be so, but, taking into consideration the remarkable myths and superstitious beliefs of the Maori concerning the lizard, I am inclined to believe that such forms represent that creature, as indeed the Maori himself asserts. An interesting name for the crocodile in Melanesia is *mokotolo*, with which may be compared the Maori *moko*, a generic term



Grotesque figures termed *marakihau*, said to be denizens of the ocean. The whole is part of a house-wall, showing two carved wall-posts and intervening decorative panel.

for lizards. This term for a lizard is also met with in Polynesia, where it is used in the same double sense of "lizard" and "monster" that it is in New Zealand. Haddon describes carved figures of crocodiles on house-timbers in New Guinea and Borneo. Ling Roth states that lizards, crocodiles, and snakes are seen carved on old wooden coffins found in Borneo, and gives an illustration of a house in Borneo showing a lizard or crocodile

carved on one of the timbers. If size is any criterion it should represent the latter creature.

It is quite probable that the introduction of the lizard or crocodile into carved designs originated in the western Pacific, possibly in Indonesia, and was not a local growth. The natives of New Guinea speak of man-eating crocodiles, and among the Masingara Tribe are seen well-carved figures of

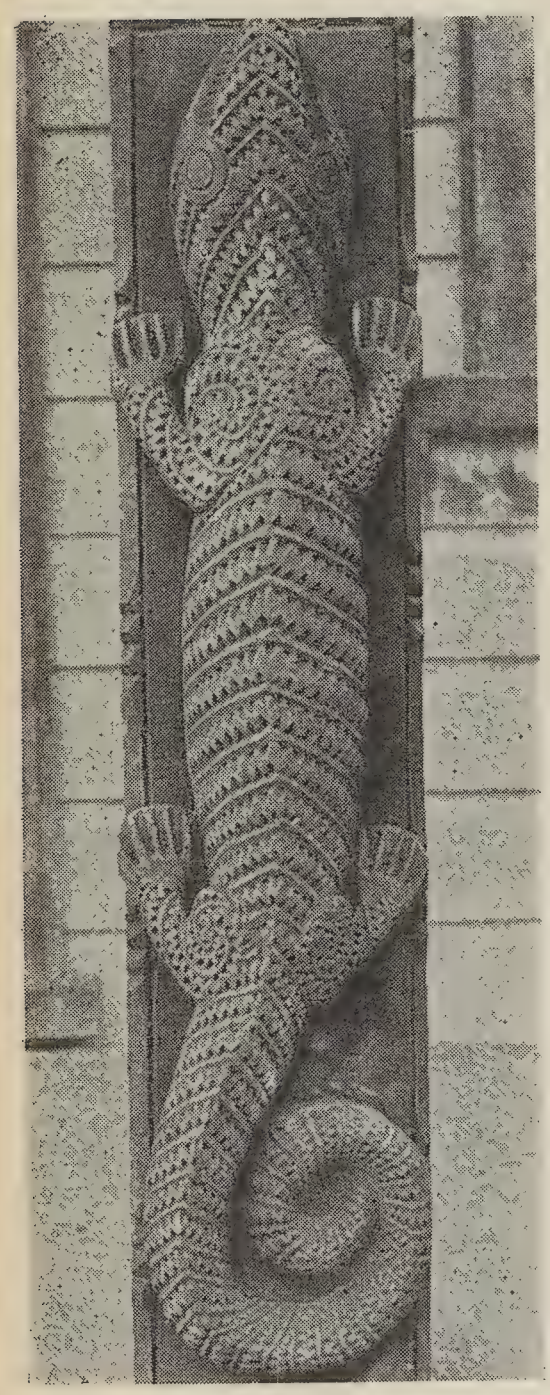
Pare, or lintel, on *wharepuni*, Koriniti, Whanganui River, N.Z.

Lizards on lintel (*pare*) of Maori house, Rotorua.

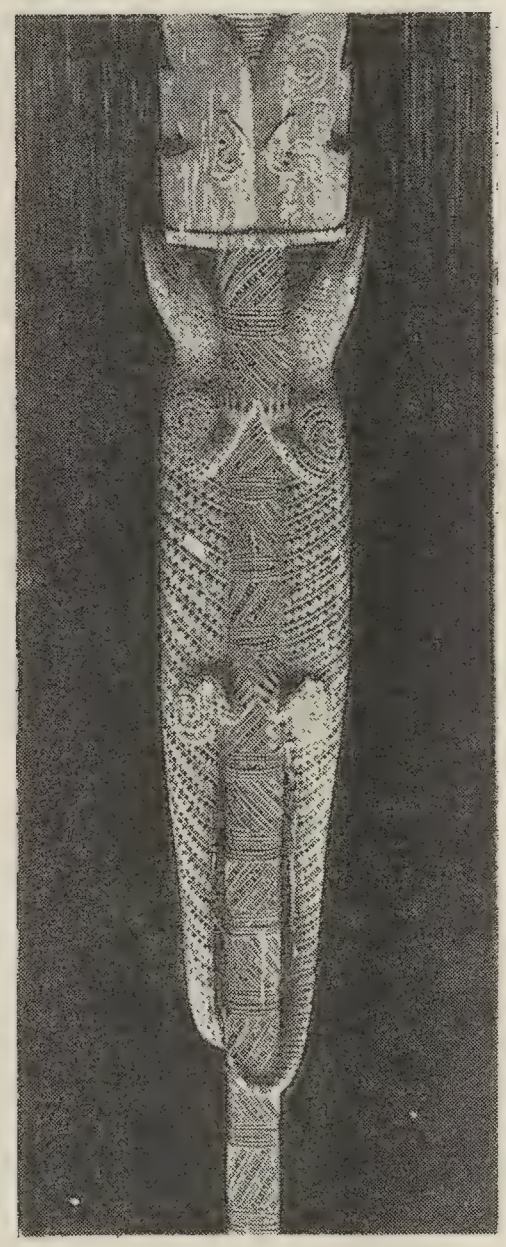
crocodiles. These figures are used in certain ceremonial dances; they are at such times anointed with fat, and offerings are made to them. The fact that the word *moko* is used in the western Pacific to denote a crocodile, and in New Zealand is applied to fabulous man-eating saurians as well as to the lizard, is both interesting and suggestive.

Now, it may be that memories of crocodiles of other lands influenced the Maori in his carving of saurian creatures on his house-timbers, but the evidence of such a former knowledge of them seems rather to be preserved in the belief in the existence of *taniwha*, described as huge saurian,

man-destroying creatures frequenting deep-water streams and rivers. Folk-tales concerning such mythical animals are common in all parts of New Zealand, and are also met with in the isles of Polynesia. In Wilkes's *Narrative* we are made acquainted with a Samoan belief in a huge lizard-like creature, provided with scales and sharp teeth, that lives in streams. Captain Cook gave us our first note concerning our local *taniwha*, as obtained from a South Island native: "We had another piece of intelligence from him, more correctly given, though not confirmed by our own observations,



Lizard carved on the post supporting end of a ridge-pole, Rotorua.



Two lizards carved on post supporting ridge-pole of house at Whakarewarewa.

Profile of lizard carved on the post supporting ridge-pole.

that there are snakes and lizards there of enormous size. He described the latter as being eight feet in length, and as big round as a man's body. He said they sometimes seize and devour men; that they burrow in the ground, and that they are killed by making fires at the mouths of their holes. We could not be mistaken as to the animal, for, with his own hand, he drew a very good representation of a lizard on a piece of paper, as also of a snake, in order to show what he meant." It is clear that Cook had not learned to accept Maori romancing at its true value. In a few cases these mythical creatures are said to have lived on land, as in caves, but the majority are described as water-dwellers. We also are told of cases in which land-dwelling saurians have captured and mated with native

women. In a few instances we are gravely informed that the issue of such unions were weird beings of half-human, half-saurian form.

The Rev. R. Taylor added his quota to lizard myths when he wrote: "Black lizards, with hair or down on them, and about four feet long, are said to abound in the Greenstone Lake. A man named Hawkins, who lived in that part of the island for many years, is said to have kept one of these lizards, which he fastened with a dog-chain; they are amphibious." After this who shall blame the Maori for romancing? The same writer tells us of a large frog on the island of Mana, off Porirua, described by natives as being as large as a "small pullet," and over a foot long in its tadpole stage. It was alluded to by his informants as the *moka-mokai a Maru-te-whare-aitu* (the pet of Maru, &c.), which name denotes another mythical being having some connection with lizards. Tu-te-wana-wana and Tu-te-wehiwehi seem to be emblematical names for lizards, being names descriptive of fearsome qualities and appearance. Lizards are alluded to as the offspring of Punga, who was also the origin of insects in popular myth. Rakahore (personified form of rock) and his contemporaries are also spoken of as being connected with the origin of lizards. The Takitumu natives of the eastern side of the North Island have it that one Peketua was the origin of all lizards, and have a curious myth concerning the origin of the *tuatara* (*Sphenodon punctatum*). Long before birds appeared an egg was fashioned by Peketua, who does not appear to have known what to do with it. He took it to Tane, who said, "*Me whakaira tangata*," meaning that it should be endowed with life. This was done, and that egg

By courtesy of Mr. T. F. Cheeseman, Curator, Auckland Museum.

produced the *tuatara,* which thus preceded all birds. From eggs fashioned by Punaweko and Hurumanu came the land-birds and sea-birds. All these eggs were formed from clay. The personified form of the common green lizard is Rakaiora, who is viewed as an *atua* (or god, as we usually term it).

The lizard was viewed by the Maori as the *aria* or form of incarnation of a number of old-time native spirit gods, and the same may be said of the lizards of Samoa, according to Mariner and Turner. In both lands auguries were derived from movements of the creatures.

We note the carved figure of what is apparently a lizard on the handle of a stone adze from Melanesia, in the Dominion Museum. A wood carving re-representing a lizard appears in Mrs. Routledge's work on Easter Island. In an account of the opening of a new house the authoress remarks: "The wooden lizards were put formally on each side of the entrance to the porch." Captain Cook saw a native of the Hawaiian Isles with a lizard tattooed on his back. Lizards appear carved on the steps of stilts from the Marquesas, and Porter tells us that the natives of that group have a great dread of lizards. The crocodiles carved on the stone seats of the chiefs of Nias, and on temples of Indonesia, may have had some influence on the forbears of the Polynesian folk when sojourning in those parts. The lizard is also said to be seen on ancient gold artifacts of Costa Rica. Christian tells us that Micronesians have all the Polynesian horror of lizards, and refers the feeling in the latter people to a former knowledge of the alligator. He also remarks that the natives of Yap assert the existence of a species of lizard with two tails, and that crocodile and snake names in New Guinea in many instances coincide with lizard and eel designations current in the dialects embracing all the isles of the Pacific. These Micronesians have also a horror of the eel, and never eat it. The Mortlock-Islanders call the eel Tiki-tol, and use it for the equivalent of the serpent in the Garden of Eden. This name of Tiki, as applied to the eel, is of some interest, as will be seen in a former paper by the present writer entitled "Tane and Tiki."*

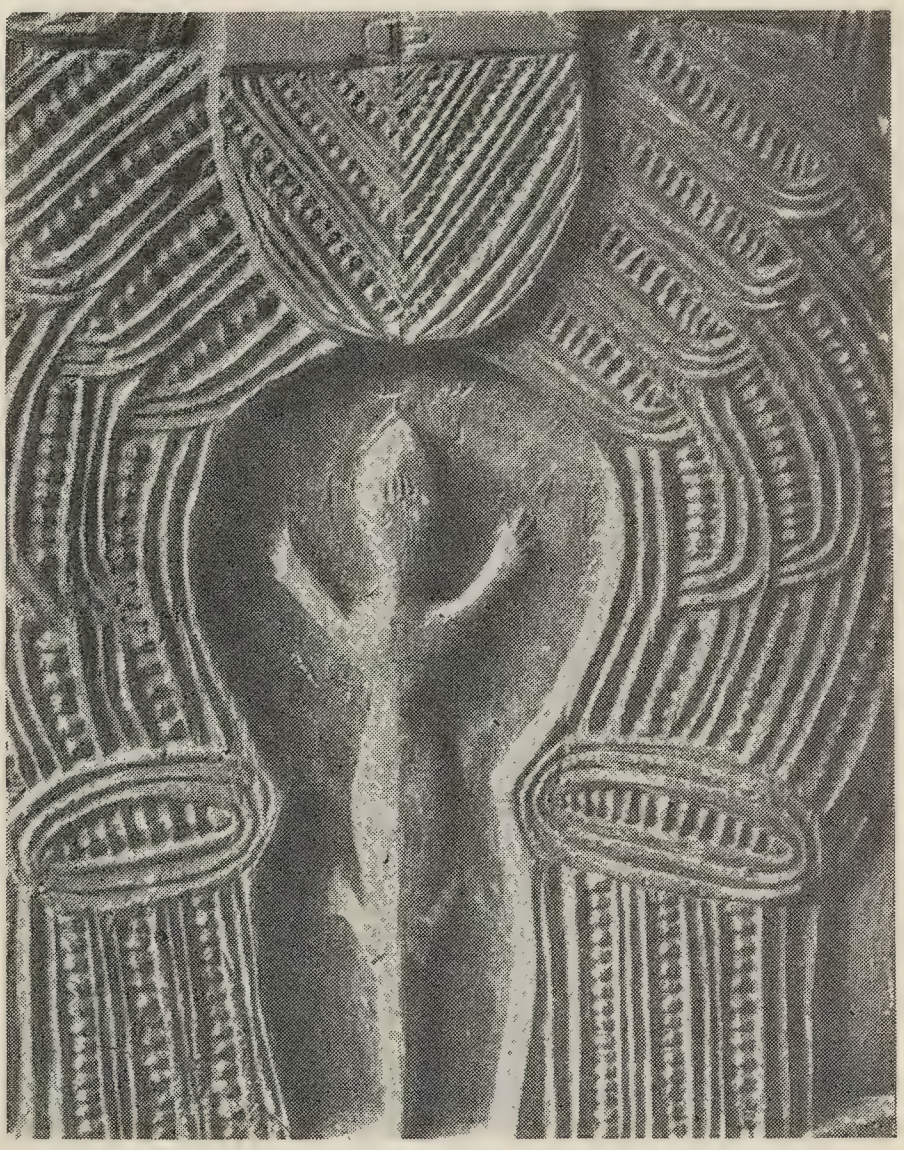
Lizard carved in space between the legs of a grotesque human figure, Rotorua.

The fear of the lizard displayed by the Maori folk of New Zealand may be traced to two causes, so far as local evidence is concerned. We have

* Not yet published.

seen that they believed it to represent one Whiro, the personification of evil and death, who ever assails and destroys mankind. Again, a belief existed that lizards were the immediate cause of disease; they were the active agents of the *atua*, or demon, that caused the affliction. Colonel McDonnell relates a story in the *Monthly Review* of a case he witnessed in which a native in robust health believed himself to be possessed of an evil spirit in the form of a lizard of the species known as *moko pāpā*. This calamity was caused by his denying the theft of some money, and he had been told by a native *tohunga* that the lizard was already located in his body and was devouring his vitals.

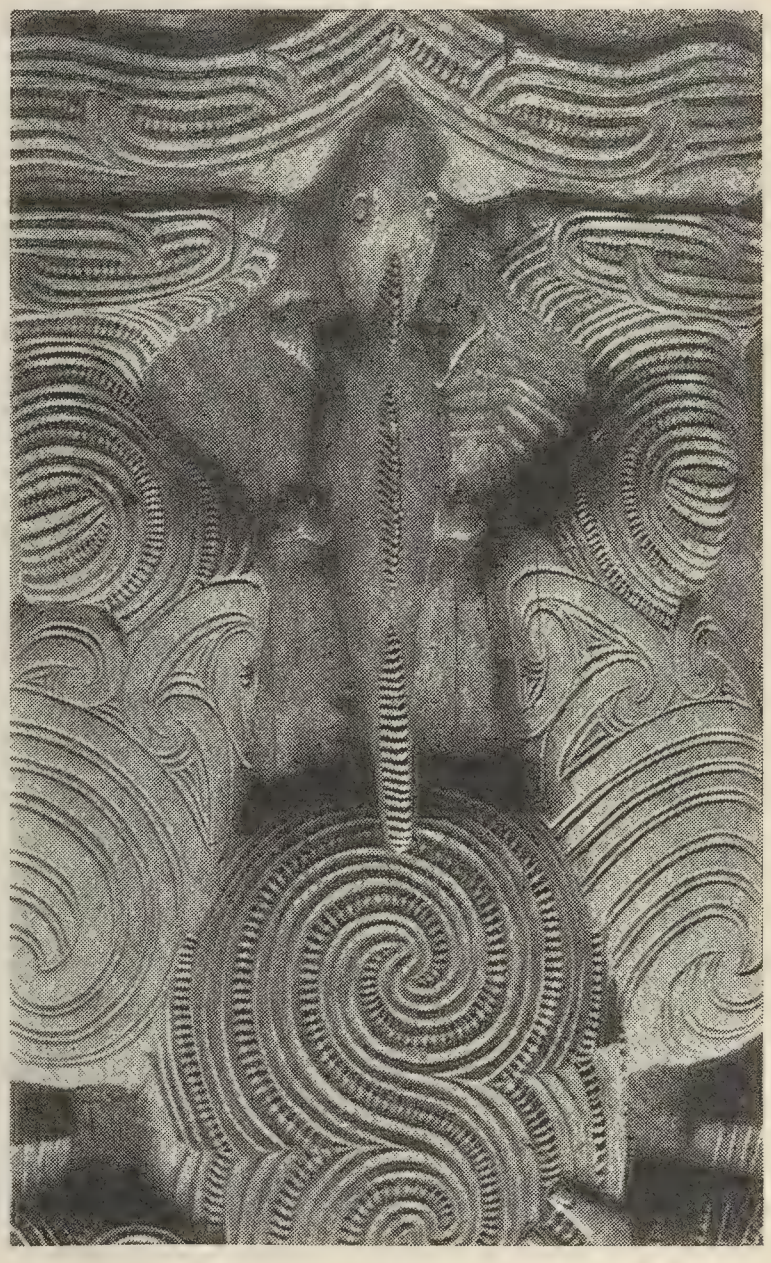
The green lizard (*Naultinus elegans*), known as *moko kakariki* to the Maori, seems to have been more dreaded than any other species, and it was perhaps the most common. It has a habit of emitting a peculiar chattering sound, a sound described by the natives by the term *kata*, a word meaning "to laugh." It was an ill-omened sound to the Maori, who was truly terrified when he heard it. Perhaps the most appalling ordeal that natives passed through was that in which a man was obliged to eat a lizard. Such occurrences were infrequent, and, so far as I am aware, connected with two functions only—the raising of an armed force in order to assist another clan, and the acquiring of the art of magic. Angas tells us of the horror betrayed in a native's face when he saw some lizards preserved in spirits in a glass vessel. Crawford and Moser both tell us of a great destruction of groves of beautiful *karaka* trees in the Whanganui valley many years ago. Some worthy prophet had told his people that all their troubles had been caused by lizards, hence those reptiles must be destroyed. The groves of trees alluded to were, he said, hiding-places for the noxious creatures, and must be done away with. In destroying the trees they also deprived themselves of a prized source of food-supplies; but superstition gained the day, and the trees fell. When caught the lizards were to be pounded, prepared in a prescribed manner, and eaten—a truly trying ordeal to the Maori. Crawford was informed that the native belief was that the European settlers wanted the lizard to destroy the Maori folk so that they might obtain possession of their land.



Roughly carved figure of lizard between legs of figure, in low relief.

The belief that sickness was caused by the gods, and was a punishment for conduct offensive to such gods, such as infringement of the laws of *tapu*,

effectually prevented anything like medical research among the Polynesians. The lizard acted as the agent of the *atua*, or spirit gods, and was believed to enter the human body and attack the vitals. In such cases, naturally, the life of the patient could be saved only by a *tohunga* or priestly medium, who, by placating the offended demon and performing a rite of exorcism, would get rid of the lizard. When a native saw a lizard on a path before him he knew that it betokened some grevious misfortune, if not death itself, to himself or a near relative. His aim, therefore, was to avert that fate; hence he would kill the reptile, get an expert to kindle an *ahi whakaepa* (propitiatory fire), and cast a hair from his head into that fire. The lizard itself was cut into pieces and thrown into the fire, while the expert repeated the necessary formula to avert the evil omen or threatened disaster. In some cases the aim seems to have been to divert the trouble, to cause it to descend on some other clan or tribe. This would probably be due to the belief that such harbingers of evil were often sent by enemies of wizard powers to afflict those whom they wished to injure. In some cases, we are told, a person who encountered a lizard at once killed it, then spat upon it, and recited a charm to *ripa*, or avert misfortune.



Base of *poupou*, or carved wall-post of a house.

The native name of the common green lizard (*Naultinus elegans*) is *moko kakariki*, *moko* being a generic term for all lizards. The tree-lizard (*Dactylocnemus pacificus*) is known as *moko pāpā*, *ngarara pāpā*, *moko tapiri*, and *teretere*. The terms *moko parae*, *moko peke*, and *mokomoko* are also applied to lizards, but we are not sure as to which species these names denote. *Kumukumu*, or *tara kumukumu*, seems also to have been a lizard-name. *Moko ta* and *ngaha* are doubtful terms. *Tuatara*, *ruatara*, *tuatete*, and *tuakeke* are all names applied to *Sphenodon punctatum*. *Kaweau*, *kawekaweau*, and *koeau* are names applied to a large species of lizard. *Williams's Maori Dictionary* identifies it with the *tuatara*, but Sir W. Buller evidently believed it to be a different species (see *Trans. N.Z. Inst.*, vol. 27, p. 94, 1895). Major Mair speaks of the *kaweau* as being a forest lizard (*Trans. N.Z. Inst.*, vol. 5, p. 152, 1873). In vol. 3 of the *Transactions*, p. 4, Sir W. Buller says: "The *kawekaweau*, a beautiful striped lizard, sometimes attaining a length of two feet, is still undescribed. It was formerly abundant in the forests north of Auckland, and is still occasionally met with." However, in the absence of specimens, the matter must remain in doubt. The Rev. R. Taylor gives *pirirewa* as a lizard-name, but no corroboration has appeared. In the South Island *toropakihi* is a

lizard-name. The name *moko-nui* is sometimes employed to denote *taniwha*, the huge reptiles of Maori myth that are said to have dwelt in these lands in former times. The name may be rendered as "big *moko*." Williams gives *moko piri rakau* as a name for the tree-lizard (and surely it is an appropriate one), also *moko kata* as a species of lizard.

Dieffenbach gives the *mokomoko* as *Tiliqua zealandica* (*Lygosoma moco*). One is said to have been found on Somes Island, Wellington Harbour; it was dark-coloured, but with light spots. The Tuhoe natives gave me the names *mokomoko*, *moko kakariki*, *moko tapiri*, *koeau*, and *tuatara* as being those of the species of lizard found in their district. Hence they seem to look upon the *koeau* (*kaweau*) as a different species to the *tuatara*. My worthy friend Tuta Nihoniho, of the East Coast, told me that the *mokomoko* is a certain cure for toothache. To effect the cure the lizard must first be caught, though the sufferer may not see it caught or a cure will not be effected. It is then wrapped up so that the head alone is exposed; then the head of the creature is thrust into the patient's mouth and held against the tooth, after which the sufferer bites the head of the reptile so as to crush it and cause blood to flow.

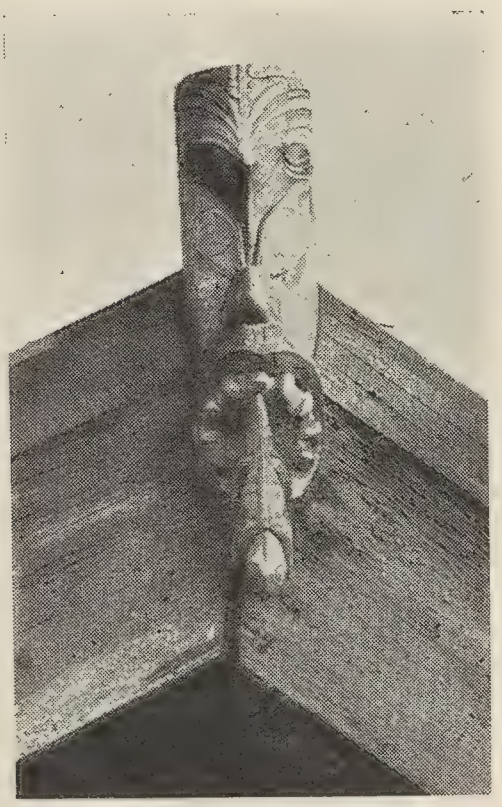
Detail of carving on door of Maori house, Rotorua.

A Tuhoe native informed me that the *koeau* is a nimble creature that grows as large as a small *tuatara*. It is said to have been a forest-dwelling creature, and was found in such places as *rua kaka*, holes in tree-trunks wherein the brown parrot breeds. The young of the *koeau*, in the form of a maggot-like creature (*iro*), are said in popular myth to be found in such holes. It was deemed unlucky to see a *koeau*. As an old native said to me, "*I kitea tetahi e Te Rangiua, na kua mate katoa o na matua*" ("One was seen by Te Rangiua; now all his elders are dead"). Another native remarked that the *kaweau* represents the souls of the dead forbears of any person who sees it, and is a sign from them that the time has come for him to join them in the spirit-world.

Old natives tell us that in pre-European times the *tuatara* was an article of food in this land, and this statement is borne out by the numbers of remains, usually jaw-bones, of these reptiles found in old middens and about old oven-pits. Such remains have frequently been found in the vicinity of Wellington. Natives of the Bay of Plenty district state that the practice was a common one with their ancestors, and quote

the following sayings in corroboration: *Ko Putauaki te maunga, he ngarara tona kai* (Putauaki is the mountain; its food product is the lizard). Putauaki is the native name of Mount Edgecumbe. Another is: *Ko te kekerewai, ko te tuatara nga kai o Wai-o-hau* (The green beetle and the *tuatara* are the food products of Wai-o-hau). This beetle (*Pyronota festiva*) was formerly eaten by the natives. The two places named were famed haunts of the *tuatara*. Women were not allowed to eat these reptiles. It was said that if they did so then they would be attacked or surrounded by numbers of such reptiles. On the Rurima rocks off Matata the *tuatara* is found in the same holes as are occupied by the *kuia* (a petrel), and of this bird the Maori says, "*He iro nona te tuatara.*" This alludes to a local superstition to the effect that the *tuatara* develops from an *iro*

Lizard carved on a *koruru*, the carved grotesque head covering the join of the large boards of a house-front.



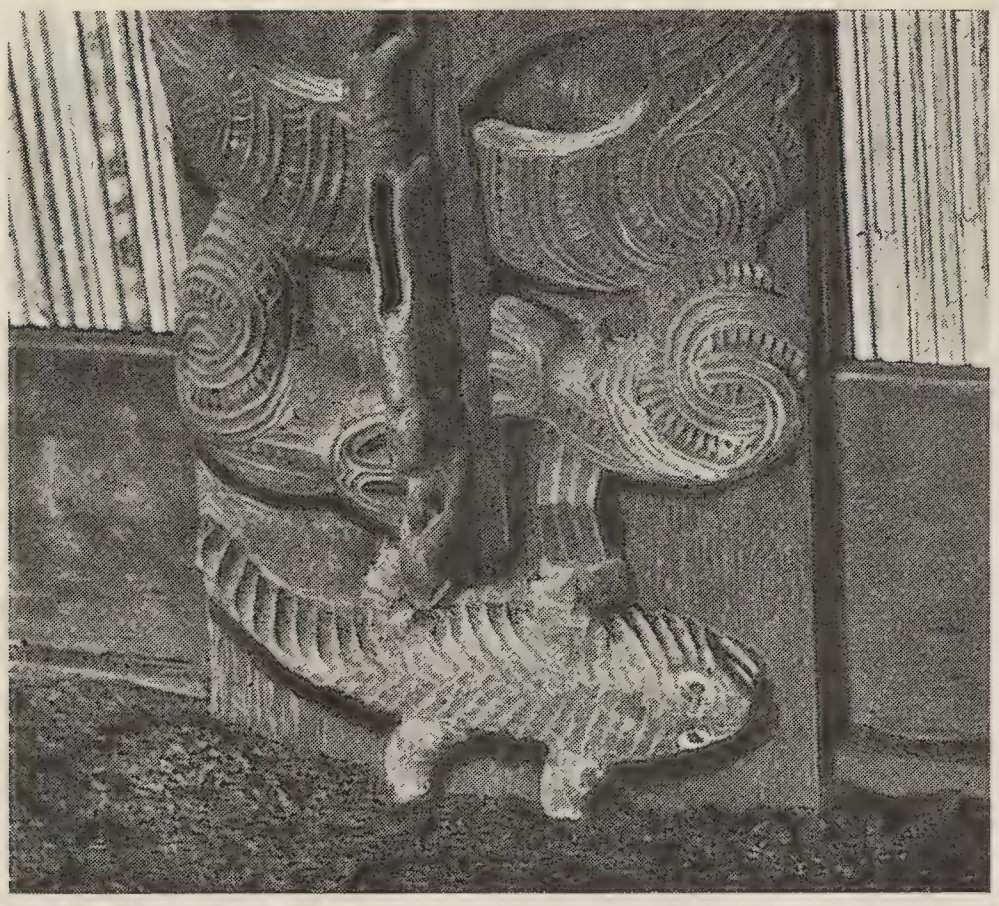
Lizard carved in place of a tongue on a *koruru* at the gable of a house.

(maggot, or something similar) proceeding from the petrel. A similar quaint belief is that an *iro* found under the young of the *tihe* (stitchbird, *Pogonornis cincta*) in the nest develops into the *moko tapiri*, or tree-lizard. Yet another of these absurd beliefs is that the shining cuckoo is the offspring of the tree-lizard.

An old fable tells of a contention between the *tuatara* and the shark. The shark wished the lizard to go with him that both might become denizens of the ocean. The latter objected to leaving the land, whereupon the shark said, "Very well; you stay on land, and be loathed by man." Replied the *tuatara*, "It is well, for that is one of my powers. But you will be caught by a hook, and your head will be battered with a root-pounder, after which you will be hung up and dried." Both these things have come to pass, for the lizard is a fearsome creature in the eyes of man, while all know that the shark is caught, killed, and dried by man to serve as food.

The *moko kakariki*, said an East Coast native, is a reptile possessing supernormal powers. It was tended by one Tama-i-waho in the region of Tiritiri-o-matangi, the eleventh of the twelve heavens, counting upwards. It was brought down to earth, where Peketua became its guardian, and he treated it as an *atua*. It had the power of moving through space, and when it did so some serious trouble was at hand, for it was a *tohu mate*—an ominous occurrence. A lizard of this species was, we are told, used as a *whakahere*, or conciliatory offering, when the *tua* ceremony was performed over the son of Uenuku; hence he was named Rakaiora.

If an armed force encountered one of these reptiles on its way to attack an enemy, that force would at once return home. To continue their journey would be to court disaster. Natives tell us that the male of this species is of a dark-green colour, while the female is a light green. This species of lizard was employed as a *whatu* at the erection of a *tapu*



Carved base of a *poupou*, or wall-post of a house.

school of learning, or other important building. It was buried at the base of one of the three posts supporting the ridge-pole, and acted as a kind of talisman, preserving the welfare of the occupants of the place. Evidently the reptile was in this case viewed as a guardian, just as lizards were located at burial-caves and at trees much resorted to by bird-snarers, as guardians of such places. The *moko tapiri* was often used for this purpose. In the case of a tree, the lizard guarded the material *mauri* of the tree—a form of talisman, usually a stone, that represented the vitality of the tree and its productiveness. We are told that a *moko-peke* was stationed as protector of a burial-cave in many cases. This may or may not be a general name for lizards; the question has not been decided. The famed ancestor Tamatea of Takitumu is said to have carried three lizards about with him during his journeyings—an unusual act. Possibly they were *aria* of *atua*—forms of incarnation of so-called gods. These three reptiles were named Tapu-te-ranga, Pohokura, and Puke-o-kahu. The first-mentioned name is that of the islet in Napier Harbour that we call Watchman Isle, and also of the rocky islet at Island Bay, Wellington. Tamatea is

said to have left the one named Tapu-te-ranga at Ahuriri, so that probably Watchman Isle was named after it.

Regarding the mythical *taniwha* of Maori folk-lore, concerning which many stories are on record, a favoured method of destroying such monster saurians was to lure them into a house, which was then barred and burned. In his work on the Caroline Islands F. W. Christian mentions a similar tradition of a huge man-eating lizard that swam into a harbour and took up its abode on an island. It proved so great a scourge that it

Two lizards carved between the limbs of a peculiarly grotesque figure having a *manaia*-like head. From Maori house at Whakarewarewa.

Grotesque figure.
[*Pulman, photo.*

was proclaimed a public enemy, and was destroyed in the above-mentioned manner.

The *moko-ta* is yet in doubt. A Tuhoe native described it as a kind of death-watch heard chirping in thatched-hut walls. A Whanganui native stated that it is a small species of lizard having but two legs. The belief that the lizard is connected with death is widespread. The Algonguin Indians of North America held that it caused death by sucking a person's blood.

In King's work on the Gnostics appears the following: "The lizard, which was believed to conceive through the ear and to bring forth through

the mouth, is the type of the generation of the Word—that is, the Logos or Divine Wisdom." This would serve to explain the appearance of a lizard upon the breast of certain figures of Minerva. In vol. 19 of the *Journal of the Polynesian Society*, p. 225, occurs a reference to a paper by Miss Buckland, in which she refers to certain figures noted in widely separated places. Many of these show a man holding a lizard, "the tongue of the reptile being attached to that of the man, as though the latter were receiving inspiration or some special endowment from his totem."

Thomson, in his *Story of New Zealand*, states that the Maori believes that the spirits of his forbears revisit the earth in the form of lizards. This is certainly not a common belief, but as *atua* were sometimes represented by lizards, and as some *atua*, or gods, were deified ancestors, then there may be a modicum of truth in the statement. In many parts of Africa the natives believe that the lizard brings death to man.

Flute in British Museum, from H. D. Skinner.

J. G. Fraser deems it probable that the fact that lizards change their skins led to a belief that they live for ever, a belief that seems to have been also connected with snakes. He mentions a belief of certain folk of Cochin-China to the effect that the lizard caused permanent death to enter the world (see *The Belief in Immortality*, vol. 1, p. 74).

The representations of the lizard in Maori decorative art seem to have been confined to wood-carving, and did not appear in painted designs. In some cases a lizard is carved in relief on the body of a human figure. In a number of cases a lizard seems to take the place of the projecting tongue so frequently seen in native carvings. Often it looks as though the lizard was being eaten, and the constant association of this reptile with representations of the human figure is significant. Sometimes the lizard is shown with its head in a person's mouth, and I have seen it with its head and fore feet hanging out of the mouth. In one carving a man is grasping a lizard by the tail and is apparently thrusting it into his mouth, which reminds us of Miss Buckland's remarks.

Lizards were viewed as desirable guardians of boundary-stones, inasmuch as their powers enabled them to punish meddlers with swift severity.

THE CASE FOR THE ELECTRIC LOCOMOTIVE.

By H. R. HALLORAN, M.E., M.I.E.A., Assoc.A.I.E.E.

MUCH has been written in the last few years on the subject of railway electrification, with particular reference to the improvements in performance obtained from electrical locomotives in comparison with steam locomotives. For the information I am submitting to you I have drawn to a great extent on these publications.

Our present knowledge of the relative merits of steam and electric traction is based upon experience, and indicates that the claims made of the superiority of steam traction will not bear examination.

While not strictly pertinent to the subject, the claim that a 3 ft. 6 in. gauge is equal to, if not better than, the standard 4 ft. $8\frac{1}{2}$ in. gauge is decidedly open to question. The claim can only be defended on the assumption that the loading-gauge will never be altered, and that on no condition will a greater axle-load than that at present utilized in New Zealand ever be permitted. We must assume that any future extensions to the service will be made by building rolling-stock and locomotives to suit the existing track and tunnels, and that at no time could any attempt be made to improve these so as to meet the demands of heavier traffic which are sure to develop as the population of the country increases. It is generally accepted that from theoretical conditions the broader the gauge the greater the allowable weight and height of locomotives and rolling-stock if the same degree of security be maintained against the equipment turning over, due to bad condition of track, failure to take curves at the speeds for which they were designed, improper distribution of loading in the wagons, and any combination of these conditions.

In the United States of America there has been a decided tendency to increase the tonnage of train units, and I have no doubt that this tendency will develop here as traffic increases to saturation-point. As an instance of this tendency I would mention the following figures for one of the latest Mallett compound steam locomotives: Height over smoke-stack, 16 ft. $7\frac{1}{2}$ in.; maximum over-all width, 12 ft.; load per driving-axle, 61,700 lb. There is no indication that the limit of size has been reached in this design. Many of the executive officers of the larger railway companies of America are of the opinion that locomotives of even greater power than those so far built are desirable, and even necessary, if the future transportation requirements of the country are to be efficiently served. At present the maximum sustained power which can be delivered by a steam locomotive seems to be fixed by the limits of the grate-dimensions, which in turn are governed by the permissible width and length of firebox, which in the above engine is $108\frac{1}{4}$ in. by 181 in. respectively, and the grate-area is 110 square feet.

The possibility of building a locomotive of practically unlimited power, and the realization of the increased track capacity to be expected by their use, is the strongest present-day argument for electrification in the minds of railway men. Operating experience of trunk lines already equipped has shown that the increased capacity due to electrification will have

the effect of postponing the necessity for double-tracking by fifteen years.

While use of the broader gauge will permit an increase in power per axle in the case of electric and steam locomotives, this point is not of great economical importance in the electric locomotive. The reason for this is that there are no physical limitations to the length of electric locomotives, or to the number of their axles, and therefore locomotives of greater length, as built for the narrow gauge, will lose nothing in efficiency, reliability, or riding-qualities, and, including a small possible increase in cost of such construction, might possess some advantage in the way of reduced axle-loads.

Motors are now being built by the General Electric Company for 3 ft. 6 in. gauge with continuous capacities of 320 b.h.p. output, and giving locomotive-axle weights of less than 18 tons, or 17·8 h.p. per ton. We must not forget also that the continuous capacity of an electric motor is based on the power delivered at the axle being maintained at full value without any restrictions as to time. This is quite a different thing from the maximum figure of 15 h.p. per ton mentioned as having been delivered by steam locomotives. We believe it may safely be stated that such motors are capable of meeting any possible future power requirements even on narrow-gauge railway-trains. You will therefore appreciate that the narrow gauge, while limiting seriously the development of steam locomotives, does not affect the ultimate design of electric locomotives, which can be built, even on this gauge, of far greater capacity than the present or immediate future requirements demand. It is not merely a matter of opinion, but a fact which can be very easily substantiated, that the electrical locomotive per unit of weight is infinitely more powerful than the steam locomotive. Consideration of the following will make this point obvious. The steam locomotive is a complete power plant itself, and must carry its own water and fuel in addition to its power-generating and transmission gear. The electric locomotive, on the other hand, is required only to transmit power and not to generate it. An interesting illustration of this point is contained in an article by Mr. A. H. Armstrong, chairman of the electrification committee of the General Electric Company, from which the following information is extracted :—

" The Mallett locomotive referred to above weighs 898,300 lb. in working-order with tender. The maximum rating given by the makers of this engine is 4,700 indicated horse-power, or 4,250 maximum b.h.p., equivalent to 192 lb. weight per b.h.p. The C.M. St. P. electric freight locomotive weighs 576,000 lb., with motors rated at 3,440 continuous b.h.p., giving a weight of 178 lb. per continuous b.h.p., and more than twice this value for short periods. The actual excess weight per b.h.p. of the steam locomotive is much greater than that shown above, as, owing to the maker's basis of rating, boilers must produce steam at the rate of 140,000 lb. per hour, or at 12 lb. of steam per square foot of heating-surface. Assuming an evaporation of 9 lb. of steam per pound of fuel, the locomotive would have to burn 143 lb. of coal per square foot of grate-area per hour. It is very doubtful if more than half of this duty could be consistently and continuously maintained in service."

Locomotive engineers are accustomed sometimes to argue that the maximum tractive effort of the steam locomotives is a continuous effort. This is correct while fuel and water are on the engine and tender, but it is usually found necessary to take water every sixty or seventy miles, and

coal every one hundred and fifty miles or thereabouts. The rating, therefore, is not a continuous rating, but the rating of the locomotive for a period during which it could operate without recoaling and rewatering. On the other hand, the continuous rating of an electric locomotive is the rating of the locomotive while in continuous service, and is not subject to deductions on account of stoppage.

The continuous tractive effort of an electric locomotive is sufficiently great for the average duty in the service for which it is designed. The tractive effort, owing to the ideal characteristics of the series electric motor, can be increased materially on hills, or at reduced speed can be maintained for periods up to, say, one hour. This tractive effort is limited by the weight on the drivers and the coefficient of adhesion between the driving-wheels and the rails. This coefficient is generally accepted as 18 per cent. when running. In addition to this, for momentary pinches the electric locomotive can develop a tractive effort up to 30 per cent. or more of the weight on its drivers, without in any way distressing the motors. As coefficient of adhesion is generally taken at 25 per cent. at starting, the electric locomotive is easily able to start the train up to the draw-bar pull which will make the wheels slip.

It will be seen, therefore, that the electric locomotive is very much more flexible than its steam prototype, and can be designed more closely to meet the conditions of service than can any steam locomotive, which must be designed for the limit rather than the average of its service. Put in other words, the cylinder of the steam locomotive must be designed with sufficient capacity to give its maximum tractive effort. This indicates clearly the reason of the steam-locomotive supporter's remark that the limit of power of the present steam locomotive is seldom reached. I would elaborate this statement, and state that its limit of effort never can be reached except at starting.

To illustrate further the relative power to weight ratio of the steam and electric locomotive, the following discussion of the possibilities of electric-locomotive design, taken from information published in the United States of America, may prove of interest. Mr. A. H. Armstrong considers the locomotive primarily as a hauling-machine, its design being defined by recognized limits, such as maximum degree of track-curvature, coefficient of adhesion between driving-wheels and rail, gross weight and dead-weight per axle, tracking-qualities at high-speed, &c. He further postulates that the locomotive should be simple in construction, and reliable and adaptable in operation, and capable of being maintained in condition for a reasonable percentage of its cost. The following list covers the generally accepted constants governing locomotives designed in the United States of America :—

TABLE 1.

Limiting gross weight per axle	60,000 lb.
Limiting dead-weight per axle	18,000 lb.
Limiting coefficient of adhesion—	
Running	18 per cent.
Starting	25 per cent.
Maximum curvature	10°.
Maximum rigid wheel-base	18 ft.
Maximum speed on level—	
Passenger	65–75 m.p.h.
Freight	25–30 m.p.h.
Maximum draw-bar pull	150,000 lb.

While from this it will be seen that 60,000 lb. per axle has generally been accepted as a limiting condition for steam-engines, it is well known that an impact equal to at least 30 per cent. in excess of this figure is delivered to rails and bridge structures, due to the unbalanced forces inherent in a steam locomotive. From actual tests it has been found that a materially higher limiting weight may be taken for electric locomotives without exceeding the destructive effects now experienced with steam-engines having this axle-load. However, owing to the flexibility of electric-locomotives design there is no need to exceed steam practice in this respect.

Accepting the Mikado and Mallett as the highest developments of steam road and helper engines for freight service, a general comparison is drawn in the following table with an electric locomotive that it is entirely practicable to build without in any respect going beyond the experience embodied in locomotives now operating successfully :—

TABLE 2.—COMPARISON OF STEAM AND ELECTRIC LOCOMOTIVES.

——	Mikado.	Mallett.	Electric.
Type	2–8–2	2–8–8–2	6–8–8–6*
Weight per driving-axle ..	60,000 lb.	60,000 lb.	60,000 lb.
Number of driving-axles ..	4	8	12
Total weight on drivers ..	240,000 lb.	480,000 lb.	720,000 lb.
Total weight, locomotive and tender	480,000 lb.	800,000 lb.	780,000 lb.
Tractive effort at 18 per cent. co efficient of adhesion	43,200 lb.	86,400 lb.	129,600 lb.
Gross tons, 2-per-cent. grade ..	940	1,800	2,820
Trailing tons, 2-per-cent. grade ..	693	1,495	2,430
Speed on 2-per-cent. grade ..	14 m.p.h.	9 m.p.h.*	16 m.p.h.
Horse-power at driver-rims ..	1,620	2,080*	5,570
Indicated horse-power at 80 per cent. efficiency	2,030	2,600*	..
Trailing-ton miles per hour on 2-per-cent. grade	9,700	13,500*	38,800

* These figures are those given by Mr. Armstrong, but reveal obvious discrepancies.—EDITOR.

This analysis brings out the fact that to equal the hourly ton-mile performance of one electric locomotive it would require three and four steam locomotives and engine crews respectively for the Mallett and Mikado types.

The electric locomotive has demonstrated its very great advantages in relieving congestion on single-track mountain-grade divisions. The number of meeting-points on a single-track line increases as the square of the number of trains operating at one time, and is proportional to the average speed, so that it will be appreciated what an advance in mountain railroading is opened up by the adoption of the electric locomotive. Furthermore, the electric performance as tabulated above can be obtained with each individual locomotive regardless of climatic conditions, efficiency of the crew, or time that has elapsed since shop inspection and overhaul, and with a demonstrated reliability that has set a new standard in railroading. In view of the facts, it is therefore a modest claim to make that by the adoption of the electric locomotive the daily tonnage-capacity of single-track mountain-grade divisions will be increased fully 50 per cent. over possible steam-engine performance.

This is not the whole story. The electric locomotive loses no time taking on coal or water, has no fires to be made or to be cleaned, is commonly kept in service between one thousand and three thousand miles without inspection, and very rarely requires extensive repairs or general overhauling. This results in a large increase of the hours of active service during the year. In accordance with published statements of officers of the Chicago, Milwaukee, and St. Paul Railway, each electric locomotive has replaced an average of three and a half steam locomotives—that is, the Mallett compound and others—on the Rocky Mountains and Missoula divisions.

The train resistance at starting is about 20 lb. per ton, and to start a train the steam locomotive must be of sufficient cylinder area and steam-pressure to overcome this initial resistance. Once the train is started, the resistance drops very rapidly to minimum at about fifteen miles per hour, and then rises with the speed. But even at ninety miles per hour the train resistance for passenger-trains is somewhat less than the train resistance at starting. Now compare these conditions with those occurring in an electrically operated train fitted with the standard motors with series characteristics, and assume again that the maximum speed required is somewhere about sixty miles per hour. The train resistance at this figure is somewhere about 11 lb. per ton. We would design the motors to give a draw-bar pull at a rated load of a little bit more than 11 lb. per ton—say, 12 lb. per ton. Then, seeing that the motors have series characteristics and that they would at starting be rotating slowly, they would, owing to their characteristics, be capable of developing a very greatly increased torque, and would easily overcome the train resistance of 20 lb. or even 30 lb. per ton over the starting-period. This, of course, is only necessary until the train reaches a speed of four or five miles an hour, at which point the train resistance has fallen very close to its minimum value. The only thing which limits the starting tractive effort available with a series motor is the total weight of the locomotive needed to prevent the wheels slipping. This is really only repeating the well-known fact that for traction purposes the series characteristic of the electric railway motor is ideal.

Mr. Jenkinson's claims of what a modern superheating locomotive will do appear quite untenable. As an illustration of this, one of the most ardent advocates of steam locomotives in the United States of America—A. W. Gibbs, chief mechanical engineer for the Pennsylvania Railways—has stated that the best result he had been able to obtain for steam locomotives, including stand-by losses, was slightly under 6 lb. of coal per horse-power-hour. On the Chicago, Milwaukee, and St. Paul Railway extensive tests were made, extending over a considerable time. The average coal used per horse-power-hour on all locomotives was 7·86 lb. The best individual figure was 5·78 lb. Admittedly in both cases the coal was probably not 14,000 B.Th.U., but 11,740 B.Th.U. per pound—that is to say, it was not picked coal, but coal such as would normally be used in locomotives. The horse-power was obtained, I believe, by indication and dynamometer cars.

The results given above are two to five times the value of fuel-consumption required to deliver an electric horse-power-hour to a locomotive from a modern steam-turbine plant.

These ratios are, furthermore, in keeping with theoretical considerations if we consider that the available energy in the steam, assuming an

adiabatic expansion, working from atmospheric pressure to a vacuum of 28½ in. is approximately equal to the energy given up by the steam when working between 180 lb. and 1 lb. gauge-pressure. The condensing steam turbine, therefore, has an opportunity of extracting from the steam about twice the energy which is available to steam locomotives within its limited non-condensing range.

There are other economic possibilities which may be applied with advantage to a stationary power plant, which would not prove feasible or possible on a locomotive. Among these are the following: (1.) Use of water-tube boilers. (2.) More efficient design of furnace, such as using a larger combustion-chamber, improved distribution of the hot gases by means of baffflers, and reduction in radiation losses. (3.) The use of fuel-economizers, recovery of heat in the condensate regulation, and control of the heat balance. (4.) Operation of the boilers at or near the rating at which they will give maximum efficiency. (5.) Accurate regulation of the air used for combustion by the use of carbon-dioxide recorders, and analysis of the flue-gases. (6.) Operation of the power plant at a load-factor of 40 to 60 per cent. instead of the 10 to 15 per cent. applying to the locomotives. (7.) If electric power is also produced for industrial purposes, a reduction in cost is made possible by reason of the diversity factor caused by variation in the peak-load demands of the various industries. When consideration is given to these factors it may safely be stated that the adoption of electrical haulage will produce a saving of one-half to two-thirds of the coal taken by steam locomotives in the same or similar service. With allowance for fixed charges, cost of labour for operation, and losses in transmission and distribution systems, the electric power delivered by the locomotive has been found to reduce the locomotive-fuel cost by from 30 to 50 per cent. These figures are not estimated, but actual recorded values.

The electric drive has replaced the reciprocating engine in the industrial work because of its economy, greater flexibility, and opportunity for increasing output. The same drive will eventually cause the replacement of the reciprocating engine and the boiler plant of the steam locomotive on all important transportation systems.

While not in possession of sufficient data to properly analyse the comparative operating-costs of steam and electric haulage on the Wellington, Lower Hutt, and Rimutaka Sections, used as the basis of Mr. Jenkinson's estimates, the figures are so wide of the mark as to demand further study. The examples chosen, involving only eighteen miles of single track in one case and five miles in the other, are really too short to permit the possible economies of electrification to be realized. These economies become prominent when a reasonably extensive section is considered, and, as a rule, when the section being studied is handling traffic at or near its full track capacity. These economies are in themselves of sufficient importance to make electrification a highly attractive proposition.

I feel, however, that it is only right to point out the obvious errors in Mr. Jenkinson's basis of comparison. A definite criticism of Mr. Jenkinson's figures is impossible, as I have at hand no information as to exactly what Mr. Jenkinson has included. I have obtained, however, from Mr. J. P. Tivey the costs of an electrification scheme with which he has just been dealing, involving the electrification of a route-mileage of thirty miles, the gauge being 3 ft. 6 in. The service is much heavier than that called for on the Wellington to Lower Hutt. Two substations are included; and,

further, instead of wood-pole construction for the overhead distribution, an elaborate steel-bridge catenary construction is used. In addition to this there is installed 5,000 K.V.A. of 33,000-volt transformers, together with 33,000-volt transmission-line from end to end for industrial purposes. The total cost of all this was £94,000. Working on the same figures, the cost of substation D.C. distribution and overhead system between Wellington and Lower Hutt would not exceed £40,000, instead of £81,000.

Further, Mr. Jenkinson in his analysis assumes that electric locomotives of 70 tons each would be required. He, however, gives no reasons for the basis of this assumption. A 70-ton electric locomotive should develop a tractive effort of 52,000 lb. as a maximum, and probably a continuous tractive effort of about 20,000 lb. I do not believe that the service between Wellington and Lower Hutt could ever demand locomotives developing continuous tractive efforts of 20,000 lb. Again, it appears that if locomotives were used the weights should be somewhere of the order of 35 to 40 tons. Mr. Jenkinson has, no doubt, access to information which is not generally available, and so I am estimating that a 70-ton locomotive is necessary, although the cost which he quotes is altogether too high. It is apparently based on the cost of locomotives equipped with regenerative control equipment, which would not be used in the run between Wellington and Lower Hutt, as the advantages of regenerative braking are chiefly obtained on steep grades, where the saving in brake-shoe and tire wear is very marked. The economy in energy, while large, is only a secondary consideration.

The present-day prices of the 70-ton locomotives suggested would be about £11,000, which makes a total of £66,000 for the six locomotives which are estimated as required for this section. As a matter of fact, if seven steam locomotives are required it would not be necessary to employ as many as six electric locomotives of equivalent draw-bar capacity. Some figures were recently given in the *Railway and Engineering Review* which showed that a steam locomotive is held by the mechanical department for an average of 53·2 per cent. of its total life, the balance of 46·8 per cent. being the period during which it is available for service. (Incidentally, mention is made in this same paper that 28 per cent. of the total coal-consumption is caused while the locomotive is standing.) In the case of the electric locomotive the mechanical department consumes less than 25 per cent. of the total life, leaving 75 per cent. for useful work. Thus a little more than half as many electric locomotives are required for the same service as would be required for steam locomotives.

While this argument can, of course, be pushed too far, I believe that four, or at the most five, electric locomotives would easily replace the existing steam service. Assuming that five locomotives are required, this brings the locomotive investment down to £55,000. As a matter of fact, the above time for repairs on electric locomotives is on the high side, as will be indicated by the following relative costs of steam and electric repairs quoted by the various American railway companies. The Pennsylvania Railways have published figures giving the relative costs of repairs on steam and electric locomotives as $3,464 per year for steam locomotives and $1,303 per year for electric locomotives. These particular electric locomotives are of the earliest design of the United States, and have their motors inside the cab, being provided with side-rod drives. This construction is now entirely out of favour in America — among other things, on account of its excessive maintenance costs.

New York Central give their figures as—Steam, $2,906 per year; electric, $1,015 per year. The Baltimore and Ohio Railway give figures of $2,727 for steam and $854 for electric locomotives. As regards the Chicago, Milwaukee, and St. Paul figures, these were published about two years ago, and then gave costs per locomotive-mile per 100 tons weight as 40 cents for steam and 13 cents for electric. These figures were based on the previous twelve months' working. Later figures were published about four months ago, covering the previous year's working, and the figures in this case were 49·8 cents for steam and 9·77 cents for electric. These figures show definitely that the repair-costs and time necessary for these repairs are much greater for the steam locomotives than for the electric—in the ratio of between 4 and 5 to 1. The above figures are definite results of operating companies, and are entirely unbiased, no favour being shown either for steam or electric sections. Therefore, if the repairs on electric locomotives for the Wellington – Lower Hutt service cost £2,500 a year, as estimated by Mr. Jenkinson, the repairs of the steam locomotives should be taken at between £7,500 and £10,000 a year; so if we take the actual figures quoted by Mr. Jenkinson for the existing steam locomotives at £5,000 a year, then we can only charge the electric locomotives with a maximum of £1,700 a year. This figure does not allow for the fact that there would be only five electric locomotives as against seven steam locomotives.

I believe that the above discussion brings out the large errors which have crept into Mr. Jenkinson's comparative estimate, and consider that no benefit would be gained by further analysis of the figures. To summarize these figures: Taking Mr. Jenkinson's total working-expenses at £15,780, the total cost with electric locomotives would be about £16,000. If properly selected electric locomotives were used this figure could be still further reduced.

While the above figures have indicated that there is nothing to choose between electric and steam system on the basis of cost, I must point out that for service such as the Wellington – Lower Hutt line it is most improbable that any electrical railway engineer would consider seriously the electrification of such a line with locomotives. The obvious method would be the use of multiple-unit trains.

Coming to the question of the Rimutaka electrification, I do not propose to analyse the costs given, as, while we could possibly modify the figures and reduce the relative value as has been done above for the Wellington – Lower Hutt Section, I must acknowledge that it would be practically impossible to justify such electrification on economic grounds. The argument that it would not be justifiable to electrify the Rimutakas by themselves really has no weight, for, as mentioned previously, electrification is able to show its benefits on reasonably long sections only. If electrification were contemplated for the Rimutaka Section it would only be reasonable to consider the whole section from Wellington through Upper Hutt and right over the hills.

A big advantage of electrification would be shown by motor-car trains with multiple-unit control, as would be undoubtedly the most satisfactory system between Wellington and the Hutt, in the greater acceleration possible for electric trains, and the consequent saving in time on the run even with the same maximum speed. If trains were made up of a certain number of motor-cars and a reasonable proportion of trailers, then a much greater total tractive effort could be exerted, because limitations of draw-gear and

under-frames of the present rolling-stock would cease to be limitations for electric trains. In this way an even higher acceleration would be obtained than by using electric locomotives.

A recent report of the performance of electric locomotives on the Italian State railways contained the following information: "The electric locomotives are not permitted to have a greater weight than 15 tons per axle, which is the limit enforced by bridge-construction. The tractive effort may not exceed 10 tons, on account of the draught-gear on the cars. Under these circumstances it has been found possible to build locomotives capable of developing 2,000 kilowatts at a speed of 46½ miles per hour, with a total weight of 75 tons, equivalent to 37·2 horse-power per ton. The particular interest in this statement is that the driving-axles of these locomotives are four in number, so that each axle develops 500 kw., or 670 h.p., being between 44 and 45 h.p. per ton on drivers. This is slightly in excess of the claim that no electric locomotive could develop more than 15 h.p. per ton."

In the same report is also given the corresponding costs of steam and electric traction on these railways. The total cost included the following items applicable to the different types of locomotives: Coal-supply of locomotives; electric energy; locomotive staff, lubrication, running-shed expenses, water-supply, &c.; maintenance of locomotives; interest and depreciation of locomotives cost; maintenance of electric installation; interest and depreciation on cost of electric installation; general expenses on staff Provident Fund, &c. The total figures in lire per 1,000 metric-ton-kilometres are given as—For steam traction, 17·04; for electric traction, 7·17: giving a ratio of nearly 2½ to 1 in favour of the electric locomotive. In this particular case the maintenance of locomotives is relatively higher for the electric locomotive, being—Steam, 1·22; electric, 0·80. This is accounted for by the fact that the Italian locomotives are all three-phase, and locomotives in general have as running-gear jack-shafts with Scotch yokes and side rods, or plain side rods. Secondly, these locomotives approach more closely the steam design than the present direct-current locomotives. Further, being three-phase, the overhead is complicated and very costly as compared with the overhead system used for direct-current locomotives. This report is given over the signature of Signor Alfredo Donati, of the Italian State Railways Service.

A further report has recently come to hand, made by M. Sabouret, chief engineer of the Paris–Orleans Railway, in which he states that the electrification of the line between St. George Le Comiers and La Mure showed a saving in total working-costs of 30 per cent.

A paper by Mr. Philip Dawson, published in January last, gives some interesting tables showing some running-costs, exclusive of maintenance of rolling-stock, on a train-mile basis. The figures given are as follows, in pence per train-mile: Local passenger-train—Steam, 50·51; electric, 27·58. Through passenger-train—Steam, 41·77; electric, 26·74. Local goods-train—Steam, 108·1; electric, 64·1. Through goods-train—Steam, 66·06; electric, 52·03.

Mr. Dawson further remarks on the great advantage of electric traction in increasing the capacity of the lines. The average suburban train-speeds are 9·31 miles per hour for steam, and 21·8 miles per hour for electric. The seating miles per hour are 4,300 for steam and 6,700 for electric. He states that in practice the net hours per annum in service are found to be 4,800 out of a total of 8,760 for steam, compared with 7,700 out

of 8,760 for electric. It is interesting to note how closely these figures compare with the figures I have given for American practice. According to Mr. Dawson's figures one electric locomotive is equivalent to 1·6 steam locomotives.

Another very interesting English article, read by Sir Vincent Raven in July last year, contains the following comments. In this respect I would point out that Sir Vincent Raven is a mechanical-railway man, and not an electrical man. He states: "The case for the electric locomotive may be set out by the brief statement that it is not hampered by any of the above-named objections. In addition it possesses other important features, such as simplicity of mechanical construction and operation; increased power of acceleration; higher schedule speed due to the possibility of heavier short-period overloads, resulting in more frequent service and increased use of existing tracks; uniform turning effort, resulting in better factor of adhesion at starting and on gradients, absence of reciprocating movement, and accurate balance of all rotating parts; facilities of driving from either end of the locomotive; accessibility of the mechanical and electrical parts; better accommodation for locomotive crew by reason of increased cab area and by closing in and heating the cab; possibility of coupling two or more locomotives together under the control of a single driver."

The production of energy in a power-station rather than on the locomotive leads to a very substantial economy of fuel. On the steam locomotive it is not practicable to work at less than $2\frac{1}{2}$ lb. of the best-quality coal per brake-horse-power-hour, and very few engines can keep on doing this for any length of time. The average consumption is more like $3\frac{1}{2}$ lb. per b.h.p.-hour for passenger-engines and 5 lb. for goods-engines. For electrical locomotives, whether passenger or goods, it is possible to reduce the consumption of fuel to less than $1\frac{3}{4}$ lb. of low-quality coal per b.h.p.-hour produced on the locomotive; in other words, electrification enables the fuel-consumption to be reduced to one-half or one-third, the fuel employed being of a quality unsuitable for steam locomotives.

Experience with regard to the cost of repairs of electric locomotives working between Shildon and Newport shows that this cost is approximately one-third that of maintaining the steam locomotives which worked this traffic previous to 1915. The difference in America is even greater, as shown by above reports.

During the discussion which took place recently, under the auspices of the Institution of Mechanical Engineers, on the electrification of English railways, Mr. C. F. Bengough, chief engineer of the North-eastern Railway, referred to the fact that coal could be burnt much more efficiently at the power-station than in the firebox of a steam locomotive. On the Shildon–Newport line the cost of repairing an electric locomotive is 1·316d. per mile, as compared with a steam locomotive at 5d. in one case and 5·522d. in another.

Mr. Roger T. Smith, chief electrical engineer, Great Western Railway, made some very interesting remarks relative to certain aspects of steam- and electric-locomotive operation from a comparative standpoint during the discussion at the Institution of Mechanical Engineers on the electrification of English railways. As he argued, in the case of a steam locomotive pooling is difficult, whereas the electric locomotive can be used for at least twenty out of the twenty-four hours every day with pooling, and in some cases it has been used for twenty-three hours out of the twenty-four. The

haulage results of this and of other advantages is that, whereas each steam passenger-locomotive can haul only from 20,000 to 25,000 train-miles per annum, according to traffic conditions, an electric locomotive can handle from 40,000 to 50,000 train-miles. Thus, while a steam goods-locomotive can haul from 10,000 to 15,000 train-miles per annum, also according to traffic conditions, the electric locomotive can easily double this record. On the Newport and Shildon line of the North-eastern Railway, which is a mineral line, the electric-locomotive train-miles are just double the steam-locomotive train-miles. The ratio of average speed to maximum speed is greater with the electric than with the steam locomotive. An electric locomotive having a maximum speed of sixty miles per hour can generally maintain an average speed of 50 per cent. greater than the speed of the corresponding steam locomotive.

I must again repeat that where the number of train-miles for a given section of road is small there is very little incentive to electrify the system. The electrified sections of the Chicago, Milwaukee, and St. Paul Railway handle a freight traffic transmitting 15,500-tons-miles per mile of track per day. The average cost of repairs and maintenance of power sub-station buildings and apparatus, power-transmission system, power-distribution system, and power-line poles and fixtures as applying to the delivery of power to the trains, and also for power, heat, light, and other purposes, for the years 1917, 1918, 1919, and 1920, was 45·6 per cent. of the cost of electric-locomotive repairs. As mentioned above, the cost of repairs of steam locomotives was more than three times that of the electric locomotives, so that, taking this into account, the steam-locomotive repairs are still more than double electrical repairs.

The statement that "No reduction in train-miles expenses would result, since heavier or faster trains could not be hauled, and, in any case, the number of trains is largely governed by the time-table exigencies in studying the convenience of the public," is directly contrary to the results shown by records and statistics of operation available in America and elsewhere. Instead of running one six-car train every hour to Lower Hutt, we would probably suggest one two-car train every twenty minutes. This again points to multiple-unit train operation with motor-cars instead of locomotives. With this scheme load-factor would be vastly improved, and the convenience of the public would be better met by providing these small trains at frequent intervals rather than heavy trains at greater intervals.

NATURAL-HISTORY NOTE.

THE following interesting note on the hedge-sparrow has been received from Mr. H. Guthrie Smith, Tutira, Hawke's Bay:—

"I heard of it first at Rissington; observed by Mr. Frank Hutchinson, jun., during 1922. From later information a considerable number of hedge-sparrow seem to be in that district. One was noticed at Tutira in July, 1922. Another, or the same bird, in August, 1922. During this past winter I have also myself seen hedge-sparrow at Mr. Walsh's place, Tikokino, Hawke's Bay. For long I have been expecting the arrival of the species, as they have been common at Wellington for twelve or fifteen years."

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A SKETCH OF THE ECONOMIC DEVELOPMENT OF NEW ZEALAND.

(Continued from No. 5, Vol. 5.)

By J. HENDERSON, D.Sc.

THAT stage of New Zealand's economic history in which the principal energies of the people were directed to developing the pastoral and dairying industries to supply external markets with foodstuffs may be considered to have begun in the early "nineties" and to continue to the present day. During this period capital could be more profitably employed in clearing, grassing, and stocking new lands than in establishing manufacturing industries, and the area of land in effective use greatly increased. Owing to causes that need not here be discussed, the price of meat and dairy-produce in Europe rose to such an extent that land formerly cropped was given over to the depasturage of flocks and herds. In some years wheat and flour had to be imported. The building of freezing-works and dairy factories absorbed large amounts of capital; transport facilities by land and sea were multiplied; and exports of wool, meat, and dairy-produce increased greatly. The North Island, with a climate more genial, a topography more subdued, and a rainfall more evenly distributed, increased in population and wealth more rapidly than the South, and is now, though somewhat smaller in area, the dominant partner.

Exports must be paid for in the main by imports, and a balanced trade reduces ocean freights; the continued expenditure of capital in providing railways and roads and in developing the pastoral industries caused the prices of goods and labour to rise and to remain high: these factors operated to discourage local manufacturing. Industries exposed to external competition, such as woollen-manufacturing, bootmaking, and cementmaking, would certainly have suffered severely but for tariff assistance; others, not so well established, such as glassmaking in Auckland and the potteries of the South Island, succumbed altogether. The clothing trades (aided by duties), furniture-making (effectively protected by high freights), and

the manufacture of biscuits, confectionery, jams, and condiments expanded only sufficiently to supply the needs of the increased population. And this is, in general, the position of all the secondary industries established during the preceding stage of New Zealand's economic development. Owing to the high price of labour the exports are of raw material or of marketable products produced with a minimum of labour. Thus the bulk of the wool is sent away unscoured; fruit, in spite of almost prohibitive freights, is exported in cool chambers; and cereals, when there is a surplus, are shipped unmilled. The products of the dairying industries—butter, cheese, and dried milk—are prepared by relatively simple operations; flax, timber, and kauri-gum receive but little treatment; scheelite, not ferro-tungsten, is exported; and the greater part of the gold is not refined. Beekeeping, poultry-farming, market-gardening, winemaking, and fruitgrowing on the commercial scale are but expansions of home industries, and for the most part their products are locally consumed. Few new industries have been established during this period, and the needs of the population were probably more fully satisfied by local manufactures thirty years ago than they are to-day.

Only such other industries as supply the wants of the pastoralist or utilize the by-products of meat-works have prospered and largely increased. Under this category may be included the manufacture of sausage-skins, manures, and sheep-dips, as well as oil-engines, windmills, and farm implements generally. The necessary increase of transport facilities caused the enlargement of the various railway workshops, and during the dredging boom the foundries and engineering-shops prospered. The growing population required more houses; most of the hardware is imported, but the various industries connected with the building trade made steady progress. In particular those concerned with the cutting and working of timber expanded. A considerable export to Australia also developed. In earlier days only kauri was sent away, but the growth of dairying in Australia stimulated a demand for white-pine; and, owing to the comparative scarcity of soft woods in that country, other New Zealand timbers find a ready sale. On the other hand, Australian hardwood, and pine from the western coast of North America, are largely imported into New Zealand.

During the period under review mining made considerable progress, but owing to the great development of the pastoral industries now occupies a relatively subordinate position. Gold produced from lodes steadily increased in the first half of the period, chiefly owing to the introduction of the cyanide process, a method of extraction first tried on a commercial scale in New Zealand. Gold-dredging, the early development of which is to be credited to New Zealand miners, largely increased the amount of gold won from the gravels of the South Island. But the impetus given the industry by these means had spent itself by 1905, since when the yield of gold has considerably decreased. Scheelite-mining, which began regularly in 1899 and had been carried on in a small way for years, flourished during the war, but owing to low prices has now practically ceased. During the first decade of the century copper-smelters were erected at three points, though ore-supplies in each instance were quite inadequate for more than the briefest smelting campaign. Attempts to mine and smelt quicksilver ores at a profit failed at Ohaeawai and Karangahake, but are still being carried on in North Auckland. A few tons of manganese, antimony, and chrome ore were mined and exported, but the

deposits have not been worked for a dozen years or more. A blast furnace built at New Plymouth for smelting the refractory Taranaki ironsands has now been removed to the Parapara district, where the ore presents no metallurgical difficulty.

Coal-mining during the last thirty years has made considerable progress owing to the demands of the growing population, of the prosperous pastoral industries, and of transport. But large amounts of coal are still annually imported, although the mines of the Dominion as at present developed could readily increase their output. The plant built to distill the Orepuki oil-shale in 1901 could not be worked at a profit. The attempts to find petroleum in payable quantity in the Taranaki, Gisborne, Dannevirke, and Kotuku districts have been unsuccessful, although at the first-mentioned locality about two millions of gallons of oil were obtained, and a part was treated at a refinery, since dismantled. The price of kauri-gum (or, more correctly, resin) has steadily increased. Poor ground and areas from which the best of the gum has been removed are now being worked, and the fine particles of the resin are recovered from swamp deposits.

A few thousand tons of sulphur have been obtained from the volcanic district of the North Island. Part was exported and part used in making superphosphates, but the bulk of the sulphuric acid consumed in this industry is produced from imported sulphur. A deposit of rock phosphate near Milton has been actively worked since its discovery in 1901. The use of lime in agriculture has greatly increased of late years. The cement industry has grown, and all the needs of New Zealand can be locally supplied. Building-bricks and drain and chimney pipes are made in many localities, excellent roofing-tiles of several types are produced, as well as firebricks, refractory tiles, and gas-retorts. Stone, mostly from local quarries, has long been used in city buildings, but of late years the marbles of the Takaka–Motueka district have acquired more than a local reputation. In addition to having value as railway-ballast, the pumice river drifts of the Waikato are used in making cement fencing-posts, channel kerbings, &c. The coarser portions also serve as insulating-material in cool stores, and the finer in the manufacture of scouring-soaps. A few thousand tons are annually exported.

Following the example of Switzerland, New Zealand makes commercial use of her scenery, especially of the glaciated alpine regions of the South Island and of the volcanic wonders of the North. In part to attract tourists from abroad and in part in order to obtain some profit from sources of wealth not otherwise exploited, as well as to give sport and recreation to the people of this country, various game birds have been acclimatized in many parts of New Zealand, the rivers have been stocked with trout and salmon, and the waste lands with deer. Attempts to introduce some of the more valuable varieties of the European edible marine fishes and crustaceans into our seas have not yet attained commercial success.

The war had a most marked effect on all the industries of New Zealand. Farmers received, for all their products, assured and undreamt-of prices, which were only in part offset by the increased price of labour and necessary supplies. The high cost of transport, its uncertainty, the difficulty —in some cases the impossibility—of obtaining goods usually imported, together with the abnormal requirements of the military authorities, aided manufacturing industries already established, and encouraged the starting of others. On the other hand, the shortage of labour and fuel added much to the manufacturers' difficulties. Nevertheless all New Zealand industries,

with the single exception of gold-mining, flourished. In common with other industries, gold-mining had to bear the marked increase in cost of labour and all supplies, although its product remained at a constant price. The Hauraki mines, which produce large amounts of silver, were in part compensated by the rise in the price of that metal, and in consequence did not suffer so severely as the gold-producers in other parts of New Zealand. Many dredges and sluicing claims and a few gold-quartz mines ceased work altogether, and others had, perforce, to extract and treat only the richer portions of the deposits.

Several factors are tending to bring about a change in the direction of the economic development of New Zealand. Three of these are —(1) The fall in the price-level of commodities, (2) the approaching exhaustion of lands fit for settlement, and (3) the increase in the population.

Prices at the close of the Napoleonic wars were in general about two and a half times what they had been thirty years before the beginning of the last great struggle between England and France. The cause of this increase was not that goods were in short supply, but was the wholesale debasement of the currencies by paper-money inflation and Government loans. At the close of the war prices dropped—sharply at first—and continued to fall, with minor oscillations, till about 1848. Prices then began to rise under the influence of the gold-discoveries of California and Australia. This was due in part to the gold that actually entered the world's currency systems, but probably chiefly to the incitement to business caused by the discoveries and the rush to colonize. Prices continued to rise till 1873, for the most part owing to the credit inflations of various wars, of which the chief were the Crimean, the American Civil, and the Franco-Prussian. There was a world-wide crisis in 1873, and prices gradually fell, with minor oscillations, to the low point of 1896, the lowest in the century. The important gold-discoveries of Western Australia, Transvaal, and Klondike, combined with another series of wars, in fifteen years, brought about a 30-per-cent. rise in general prices, which was carried by the currency inflations of the late war to a peak nearly as high as that of 1809. They have since fallen sharply, and a further considerable and probably long-continued fall in the general price-level is certain. Debtors of all kinds, whether individuals or nations, who have to pay interest on the principal of loans contracted when prices and interest rates were currently high will lose most during the period of low prices. What may mitigate, though it will probably not entirely neutralize, the effect of a general fall in the price-level is the fact that a large proportion of New Zealand's exports consists of wool and meat, which, owing to growing scarcity, are likely to increase in value. For, although modern methods have hitherto been able to keep down the cost of these commodities in the great centres of population, they have had no substantial effect in increasing the total supplies. Thus in the case of wool the world's production during the last century has not much more than kept pace with the growth of population, and in the future, owing to the suitable sheep-grazing lands being now largely utilized, is likely to fall behind rather than to improve. This line of reasoning, however, does not apply with equal force to dairy-produce, which depends mainly on an adequate supply of vegetable foods for the herds. Improved methods of cultivation and the intelligent use of manures will increase the yield per acre considerably, but by no means indefinitely. Again, the present high price of dairy-produce is in part due to the

politically disturbed state of Central Europe and Russia. These large and important areas will doubtless shortly be producing much greater amounts of foodstuffs, including butter and cheese, than at present.

The prosperity of New Zealand during the last thirty years has depended on the continued growth of her pastoral industries, which in turn has depended chiefly on the increase of the area in effective occupation. This has been brought about by opening up new areas to settlement. But now the bulk of the land that can be profitably used for the production of food is occupied. In addition to the forested country of the Urewera district, the centre of the North Island, parts of Marlborough, and along the western coastal region of the South Island, the chief areas that yet remain are the pumice lands of the Taupo-Rotorua district and the valley plains of Otago, as well as the undrained swamps and the unreclaimed tidal inlets. But the great bulk of the forested areas are so broken, steep, and high that they will be more profitable to the commonwealth as woodland than as pasture; the pumice lands will require constant feeding with manures to render them productive; and to make farms by irrigation, drainage, or reclamation requires much capital. In some of the more closely settled districts are scattered farms, mostly owned by absentees or speculators, that with suitable treatment would become much more productive. These areas, in the aggregate considerable, are, however, offset by lands recently cleared and still in pasture that are unlikely ever to repay the capital already expended on them, and which within a few years will largely revert to forest. In a general way, the conclusion seems well founded that food-production in New Zealand can be largely increased only by the more intensive cultivation of lands already occupied. By this means the yield per acre will increase, but the yield per man engaged will decrease. The conversion of sheep-stations to dairy-farms furnishes examples: the dairy-farmer now top-dresses and limes his fields more frequently; the sheep-farmer will shortly follow suit with his hill pastures; indeed, for years past the whole tendency of New Zealand farming has been towards more intensive cultivation. Much has been done and much more will be done to increase productivity by using better stock, by cultivating plants and varieties most suitable to each soil and climate, and, generally, by intelligent farming. The use of power in driving milking and shearing machines enables one man to farm more land, or, if he does not increase the size of his farm, allows him a little more time to devote to it. But power—except indirectly by irrigation and drainage—will not increase the area that can be farmed, and can increase productivity only to a limited extent. Its increasing use is but a manifestation of the present tendency to more intensive farming. New Zealand, in fact, is now entering the era of diminishing return per unit of work and capital employed in the agricultural and pastoral industries, and, since profits for new capital invested in farm-lands are likely to be smaller than heretofore, money will tend to be put to other uses.

Immigrants come to a country in the hope of bettering themselves. They move in large numbers either when conditions in their native country are abnormally unfavourable or when those of the new country are abnormally attractive. The colonists who came to New Zealand in the "forties" braved a long and trying voyage to a wilderness peopled by fierce savages because they had no hope that the living-conditions in Great Britain, which had been growing more and more difficult for over

twenty years, would improve. During the "fifties" few came to New Zealand; to those who reached the Antipodes the Australian goldfields were more attractive. Nevertheless, Australian sheep-farmers came in numbers to the South Island, to an empty land where conditions were almost ideal for sheep. The gold-discoveries of the "sixties" and the general European trade depression of the "seventies" brought fresh swarms to New Zealand. The bad times of the "eighties" checked these; indeed, during the three years of "the exodus" (1888–90) the population scarcely increased in spite of the high natural increase. From the early "nineties" till the beginning of the war conditions in Europe were nearly uniformly good, and immigrants did not arrive in large numbers. But now economic pressure will cause many to emigrate; and of these, because they may no longer freely enter the United States, probably a larger proportion than of any previous swarms will come to New Zealand.

The cost of imports and the interest charges on a large external debt are met by exports. As the deflation of the world's currencies proceeds and as the nations return to a gold standard the general price-level will fall. In so far as New Zealand's exports are used to pay for her imports this fall in prices will be immaterial, but in respect to the interest charges the effect will be most unfavourable. The large external war debt bears a high rate of interest. Some of the war loans were short-dated and will probably be renewed at a less rate; on the other hand, many loans maturing in a few years were obtained when money was cheap and will have to be renewed at increased rates. The net result will be a decided increase in the total external interest bill. While prices were rising the volume of produce required to pay a given amount of interest continued to decrease; with falling prices it increases. Thus the interest rate, which, measured in terms of produce, decreased during the boom years, will increase as prices fall. If the present volume of imports is to continue exports must increase, either by augmenting the amount of commodities already exported or by finding other marketable commodities. The trade balance would also be maintained if imports were sufficiently reduced, in which case essential goods or suitable substitutes would have to be produced in New Zealand.

Of late years 90 per cent. or more of the staple exports have consisted of wool, frozen meat, dairy-produce, and other animal products, chiefly tallow, hides, sheep-skins, and rabbit-skins. The rest of the exports are made up of gold, kauri-resin, flax, and timber. All are primary products representing maxima of marketable commodities produced with minima of labour. Those susceptible of considerable and more or less sustained increase are dairy-produce and flax. The others are more likely to decrease in volume than to increase.

In the case of sheep, the flocks show a tendency to diminish, for the reason that new lands added to the sheep pastures are insufficient to compensate for those converted to dairy-farming and the growing of cereals. The amounts of the different products derived from sheep—namely, coarse and fine wools, mutton, and lamb—will vary according to the vagaries of the markets; but the aggregate production is not likely to change greatly from year to year. The value of wool and meat will probably gradually increase; but the exportable amount will probably decrease, owing to the need of the growing population and the diminishing flocks.

Dairy-produce, on the other hand, is likely to be exported in decidedly greater amount. Rich valley-bottoms and scattered areas of lowland at present used for sheep are admirably suited for milk-production. These areas are individually small, but in the aggregate considerable, and when the means of transport are improved will undoubtedly tend to become dairy land. So also will most of the areas of forest land suitable for settlement in the Urewera district, in south-west Nelson, and in Westland; of poorly farmed native lands in North Auckland, the East Cape district, and the King-country; and of the areas in various parts of New Zealand brought into use by drainage, reclamation, or irrigation. The yield of milk per cow may also be increased to some extent by careful testing and culling, but so long as the herds are chiefly grass-fed the yield is sure to be considerably less than that of Danish cows.

The exports of gold, scheelite, and kauri-resin are not likely to increase beyond their pre-war volume. The limits of the goldfields are now well known, and discoveries of new deposits will be fewer than in the past. Gold-mining is now being stimulated by falling prices, but a large increase of output is likely only by some technical advance in mining and treatment methods whereby known deposits not at present workable at a profit will be exploited. High-pressure sluicing, hydraulic elevating, dredging, and the cyanide process are examples of such improved methods. The mining of scheelite has ceased, and until working-costs greatly diminish or until the price materially rises is not likely to recommence. The output of kauri-resin, which is gradually becoming scarcer, is only maintained by adopting improved methods of working.

Since the timber reserves of New Zealand are already seriously depleted, export should be discouraged. Were the country better equipped industrially, much material now wasted at the mills could be profitably utilized.

The "flax" (*Phormium tenax*) industry, depending as it does on uncertain external markets, has from the first been subject to violent fluctuations. It is depressed at present, and a disease, known as "yellow-leaf," for which no effective remedy has yet been found, threatens it with extinction. No doubt, however, means will be devised to check the disease. The principal centre of the industry is on the swamp lands of the lower Manawatu. But in other parts of New Zealand large areas not likely to be effectively drained for many years could be used for growing flax systematically. There are several known varieties of flax, and by careful selection the yield from the crop should be improved and made more profitable.

The fur trade, though the first New Zealand industry, is not likely to increase. The fur-seal has been all but exterminated in the surrounding seas, and owing to poaching does not tend to become more plentiful. Rabbit-skins are exported in quantity, and have considerable value. In spite of many efforts, rabbits still infest large areas, and form the basis of an industry that seems likely to live till New Zealand is much more closely settled. The Australian opossum, which has been successfully naturalized, furnishes an increasing number of valuable skins.

The export of fruit will probably increase considerably. If this industry is to progress an oversea market must be found for the fruit of the rapidly growing area of productive orchards. At the present time cool storage, freight, and other charges are too great to allow of a reasonable profit to the orchardist. But the local market could be better served. Considerable

quantities of tinned fruits of kinds that grow well in New Zealand are annually imported. The products of the canning industry could no doubt be so improved and increased as to capture this trade.

The exports hitherto considered in this section are being sent away either in large or in considerable amount; but New Zealand has other material resources that will in the future furnish raw products valuable for external exchange. The extensive shallow seas surrounding the Dominion teem with fish. Why the inadequate local supplies are not increased is hard to understand; there hould be a surplus for export. The quinnat salmon, after many years of effort, has been firmly established in the rivers along the east coast of the South Island. The supply should soon be sufficient for the local market and allow the export of tinned fish.

Although no workable deposit of the ordinary commercial metals—copper, zinc, lead, and tin—is known in New Zealand, other valuable mineral substances, that up to the present have either not been worked at all or have been worked to a small extent, occur. The deposits of asbestos and talc in the Mount Arthur district, Nelson, though difficult of access, are capable of supplying all New Zealand's requirements and of furnishing valuable exportable commodities. During the last five years asbestos goods of the average annual value of £45,000 have been imported; and there is a much larger market in Australia, which also imports large amounts of asbestos. The volcanic districts of the North Island contain deposits of sulphur, of what extent is at present unknown. Sulphur is used in the manufacture of sulphuric acid, the chief reagent of many chemical industries. In New Zealand it is made from imported sulphur and employed in the manufacture of superphosphate. The pumice sands and gravels derived from the Taupo–Rotorua district also have commercial value, and are being more and more used in modern industry. The amount sent to Australia should materially increase.

Deposits of mercury-ore occur in North Auckland, where for some years efforts, more or less desultory, have been made to place the production of the metal on a commercial basis. The deposits are large enough to make this a reasonable expectation. Quicksilver is a metal produced in quantity chiefly in Spain, Jugo-Slavia, Italy, and California. The total annual production is not large—about 4,000 tons; and under existing conditions the difficulty is not one of supply but of securing a remunerative price for the output, which shows the lowest rate of increase of any of the industrial metals. Quicksilver is chiefly used in gold-saving and gilding, industries that are unlikely to require increased supplies; so that unless some new chemical or industrial use for it is found it is likely to recede in value.

The blast furnace recently erected near Parapara should be able to supply the bulk of New Zealand's requirements of foundry iron, and, when an additional furnace is built, of open-hearth steel. The furnace is favourably situated for cheap working, being close to large deposits of ore and limestone. The ore, which is a porous limonite, containing from 45 to 50 per cent. of iron, low in sulphur and phosphorus, can be readily reduced, about a ton of coke being required per ton of pig iron produced. In order to demonstrate to likely customers the quality of the iron yielded by the ore, smelting was carried on for a short time as soon as the furnace was erected, but before coke-ovens or shipping accommodation had been provided. The iron produced was a soft high-silicon iron suitable for foundry purposes. A battery of coke-ovens has since been built, and will eliminate a considerable waste of fuel, since coke used for iron-smelting

with each handling is estimated to depreciate at least 1 per cent. The coal will be obtained from the West Coast; but about half the fuel charge will consist of relatively cheap gas-coke obtained from the larger centres.

The establishment of the iron-smelting industry is of great importance to New Zealand. The cost of the iron and freight charges are saved to the Dominion, and at the same time local coal-mining is stimulated and new subsidiary industries founded.

The coal that leaves New Zealand is chiefly fuel for bunkering steamers engaged in the export trade, together with a small amount of superior coal used by the Navy. But during most years these quantities are considerably exceeded by the coal imported. The proved coal of New Zealand is sufficient for a generation, and the probable supplies much larger in amount. The most valuable fuels, the bituminous coals of the West Coast, are a luxury combining refinement of quality with shortage of supply. At the present time more than half the coal mined is bituminous, which is used in many ways for which a lower-grade fuel is quite suitable. Thus it is essential in gas and coke making, desirable for bunkering and locomotives, but could be replaced without inconvenience for use under stationary boilers and for domestic heating. There are thick extensive seams of pitch and brown coal on the West Coast that could furnish large supplies to the central portions of New Zealand, Canterbury, Wellington, and Hawke's Bay, at present using bituminous coal for all purposes. The largest single consumer of coal in New Zealand, the Railway Department, uses about 300,000 tons of high-grade fuel annually. Much of this coal is imported, whereby the Dominion's supplies are conserved; but these imports, which are a serious drain, could be avoided if pulverized coal were used. To convert the locomotives to dust-burners would, however, cost much money; but long-haulage charges would be greatly reduced, since local low-grade fuels could be utilized.

The petroleum products annually imported in large amount are likely soon to increase in price. This will doubtless cause the known petroliferous areas of New Zealand to be thoroughly prospected. This work should be undertaken only by a company with large capital reserves and guided by expert advice, since generally many dry wells have to be drilled before it can be proved whether payable oil-pools exist or not. Indications of petroleum are found over considerable areas of New Zealand, but up to the present little intelligently directed prospecting has been done.

The oil-shales of Orepuki and Waikaia, which also contain large supplies of oil, will not yield the profits of a successful oilfield. These are due substantially to the cheapness with which oil output can be developed as compared with the expenses of opening up a mining area. A well costs perhaps a tenth as much as a shaft of equal depth, and is put down much more quickly. When the oil-sand is reached further developments and working-costs are trifling, for in some cases the oil is lifted to the surface by gas-pressure and in the others has merely to be pumped. There are none of the expenses, common to other mining enterprises, of breaking ore, timbering, and haulage. These factors make successful oilfields very profitable, but they also tend to make them short-lived.

Oil produced from shale must also bear the cost of distillation before it reaches the stage at which petroleum enters the refinery. Obviously, until the value of oil materially increases, even the shales richest in oils are not likely to be treated profitably. But many shales yield by-products,

ammonia and waxes; and it is from these that the profits are made in Scotland. The New Zealand shales are rich in these by-products. But the exact nature of the shales and the mode of treatment that will yield the best results must be carefully determined, the extent of the deposits ascertained, the mining and extraction costs closely estimated, and the probable market considered before large capital is expended on a distillation plant.

In the foregoing pages an attempt has been made to show that the progressive settlement of new lands, on which the prosperity of New Zealand during the last thirty years has chiefly depended, is not likely to continue; that the tendency to intensive as distinct from extensive farming is decided; and that the returns from the land per unit of work and capital employed are diminishing. Other resources of raw material that might be exported or might supplant imports were suggested whereby the trade balance could be maintained. But the same result would follow from the establishment of manufacturing industries. The tendency to manufacture is now marked, and received an impetus from war shortages, which brought home to all the advantages of being self-sufficient as a country. The benefits accruing to Christchurch from cheap power in aiding the extension of old and the founding of new industries is manifest; and centres of population, equally with the usually conservative farming communities, are anxious to be supplied with cheap hydro-electric energy.

Water-power has certain obvious advantages over steam-power: it is inexhaustible—the streams will always be there, so that the future does not depend on a dwindling reserve; and, once the plant is installed, operating-costs are very low per unit of energy produced. Common but fallacious deductions from these facts are that hydro-electric power will be cheaper per unit than that derived from coal, and that these unit-costs are likely to decrease as the plant grows larger and older. The high cost and unreliableness of coal-supplies during and immediately after the war predisposed many to accept these conclusions. But the capital cost of most hydro-electric schemes is high compared with that of a coal-using plant producing equal energy. Again, in some cases all the energy available from the necessary initial expenditure cannot at once be profitably used, so that high prices have to be charged or interest losses carried forward, adding to the total cost of the scheme. Therefore careful scrutiny is required not only in regard to the amount and cost of the energy at the point of generation, but also in regard to the distance of transmission and the amount of the immediate and possible future consumption. New Zealand seems to be peculiarly well situated in respect to the amount and availability of its water-power, but if it is to be of use in industrial development the capital expenditure in harnessing and transmission must be low. Industry being concerned primarily with what is profitable, those localities and countries that, other things being equal, can supply energy most cheaply will become manufacturing centres.

Though power is generally the most important single factor in aiding or limiting industrial expansion, other factors are also important. Thus industry, whether concerned in manufacturing or in producing raw materials, cannot be increased faster than capital becomes available for investment. Cheap and reliable transport between the manufacturing centre and the consumer is necessary even if only the home market is supplied. All industries require careful and prudent management. Some depend for success chiefly on expert technical direction; others chiefly on skilled

labour. These, together with abundant and readily obtained raw material, constitute the principal bases of modern industrial progress.

Seeing that New Zealand's chief export is wool, it seems likely that the manufacture of woollen goods will greatly increase, and that with cheap power a large export trade will be attained. The present difficulty is the scarcity of skilled labour; the mills already in operation could employ large numbers of operatives were they available. The supply may be increased either by the slow process of training local labour or by immigration. But highly skilled artisans and factory operatives do not readily leave their homeland; even in times of economic stress such as now obtain in England it is the less competent or wholly unskilled who suffer most and in consequence emigrate in greatest number. And this difficulty of obtaining skilled labour is real and serious in establishing in any country a new industry utilizing a large amount of intricate machinery that must be tended by highly skilled operatives.

The manufacture of cotton goods is likely to be undertaken as soon as abundant supplies of raw cotton can be obtained from Australia or the tropical islands of the Pacific. This also is an industry largely dependent on skilled labour, and will probably best succeed if controlled by experienced manufacturers, who, assured of cheap power and the local market, will supply the necessary capital and labour.

Another industry of which the raw materials are now largely exported is tanning. In this, technical control is of greater importance than labour. With this industry will also develop the preparation of glue and gelatine. It would absorb large quantities of vegetable tanning-materials that could be supplied from lands unsuited for agriculture or grazing, and by using mineral tanning agents would encourage the chemical industry.

The use of clay products has become so common and so important that few people realize their value or their variety. Earthenware, vitrified goods of coarse type, refractory bricks and tiles, and gas-retorts are already produced; but there is ample raw material and a good market for sanitary ware, vitrified tiles, and various stoneware articles. The manufacture of porcelain, the highest grade of pottery, which requires great technical skill and careful selection of materials, need not be attempted.

New Zealand, which has all the material necessary for glassmaking, annually imports much glassware. Bottles could easily be made, and the better grades of glass could be imported till the industry was well established, the demand greater, and a supply of suitable labour available.

There is room for great expansion in the chemical industries—indeed, the general opinion of writers on economic subjects is that the chemical industries will in the future occupy a relatively much more important position than they do to-day. The principal raw materials used are sulphur, lime, salt, magnesia, and potash. With the exception of the last, these are obtainable, and probably obtainable in large amount. Coal, which may also be required for its heating and reducing powers, forms the raw material of many chemical products. Electrical energy may be used for electrolytic dissociation as well as for its heating and power value. In Norway the bulk of the electrical energy produced is utilized in the chemical industries, chiefly in the fixation of atmospheric nitrogen and in the manufacture of calcium carbide.

Few industries can be founded that do not in some way aid industries already established or induce the starting of others. Thus, if the

manufacture of textiles expand, the increase of wool-scouring will aid, among others, the soap and chemical industries, and at the same time make profitable the saving of wool-grease, which, when purified, is the valuable lanolin. The dyeing industry will also benefit, and, through the chemical industry, cause various raw mineral materials to be produced. The increased use of machinery in manufacture helps the engineering trade and those industries from which it obtains raw materials. Modern manufacturing is so complex that the various producing units are largely interdependent and one cannot be benefited or injured without affecting many others.

The economic development of any country is a phase of social evolution. It is to some extent under human control, though physical factors, chiefly the material resources of a country, influence the nature of the change and limit its amount. The object to be kept in view is to continue the increase of national wealth, to utilize with the utmost ultimate economy all the wealth-producing elements, but at the same time to free the process from all preventable misery. Full information as to the conditions of production, of commerce, and of transportation is indispensable. Without precise knowledge of the requirements of industry and of the location and amount of raw materials a balanced adjustment of population with local resources cannot be attained, and transport absorbs great amounts of wealth and energy. Thus there is need of a national stock-taking, not only in regard to the soil, the principal source of wealth, but also in regard to the mineral, forest, and power resources of the Dominion.

A GROWING MENACE TO OUR TIMBER STRUCTURES.

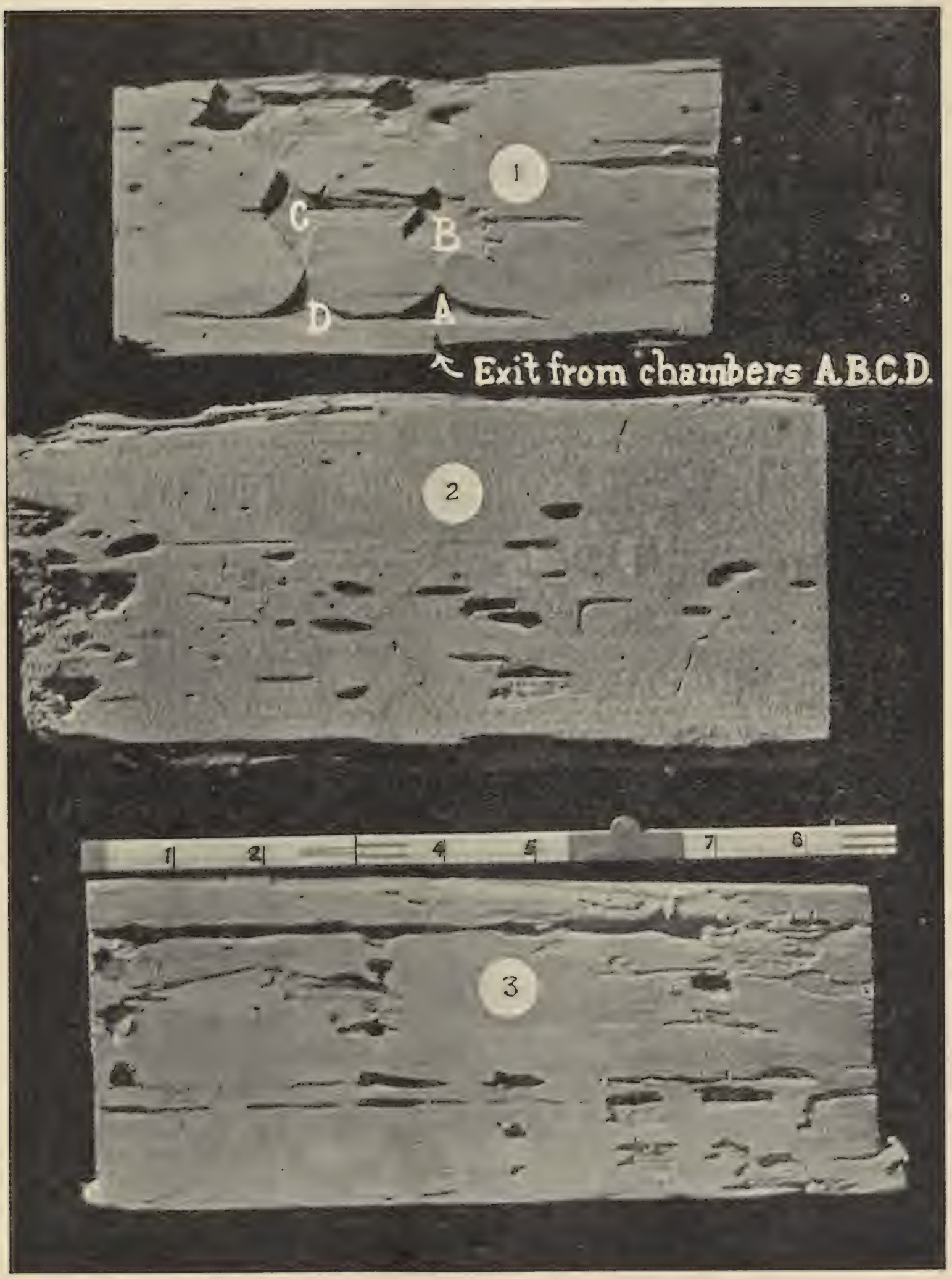
The New Zealand Variety of White Ant (*Calotermes brounii*).

By Colonel G. ARNOLD WARD, C.B.E.

THOUGH it is over thirty years since Captain Broun, formerly New Zealand Government Entomologist, recognized a New Zealand variety of white ant (which was officially christened after him *Calotermes brounii*), I have been somewhat surprised to find that a large number of architects, civil engineers, and builders, and even members of the Forestry Department, have as yet but a nodding acquaintance at the most with this destructive pest, which should rank as one of the most insidious destroyers of any structure wherein timber forms any important part. From my own professional experience of the ravages of this insect I strongly suspect that some of the recent disastrous failures of timber bridges of fair age in this Dominion have been due to unsuspected damage by the ant at some structurally vital spot. Hence a few notes of what I have personally observed of the life and work of *Calotermes brounii* may be of some service perhaps to those who may not have had equal opportunities to study its evil doings.

The Insect and its Original Home.

Writing from memory in lack of any printed record within reach, I believe Captain Broun found that this variety of the white-ant family



had its original habitat in dead puriri in the bush, in which it is a slow but very sure destroyer. Hence the unfortunate but quite pardonable vogue which puriri enjoyed for a great many years for service as house-blocks, besides its use for fencing-posts, served to bring the pest out into the

heart of all early settlements and offer it every advantage to increase and multiply, while at the same time giving it countless opportunities for changing its former monotonous food and environment.

It is, of course, in its larval stage that it does its deadly work in our timber structures, and in this form it is a grub from $\frac{1}{4}$ in. to $\frac{3}{8}$ in. in length, about the thickness of the lead of an ordinary pencil, six-legged and slow-moving, living in colonies within its selected home, where it eats out chambers of varying size and form, joined by short tunnels sufficient to allow the passage of one insect at a time. The shape and size of the original excavations appear to vary with the nature of the timber invaded, but as time passes and generation after generation of ants occupy the ancestral home, partitions appear to be removed and the cavities indefinitely enlarged: but more of this later. Then, of course, there comes for each larva its period for emergence as a winged insect, in which transformation I recently (February) surprised a colony in an old heart-of-kauri post. For the purpose of emergence a tunnel is drilled from some suitable chamber to the outer air, of just sufficient size to admit the passage of one insect. Herein lies the insidiousness of its work, in that it may make but one exit for a countless host of ants, which gives no hint of the hidden hollowness within. In the flying stage the ant is slender-looking, with long, narrow wings of a warm dark-brown colour, the creature measuring about $\frac{3}{8}$ in. in length over all.

It will be seen from what I have written above that this destructive agent, unlike many of the boring kind, shows on the surface of the timber only the most minute sign of the ravages it is carrying on unsuspected, sometimes chambering out the whole interior while leaving intact an outer shell no thicker than a visiting-card. Hence the human eye alone is almost powerless to detect its presence, and, when detected, nothing but the axe or saw will reveal the extent of the insect's work. Herein lies the danger to which this article is written to draw urgent attention.

RAVAGES OF THE LARVAE.

The photograph which is reproduced herewith will serve to show the work of the pest in kauri timber, where it has not proceeded to a very serious stage. Nos. 1 and 2 show sections of part of the same piece of infested timber cut at a right angle to each other, and showing how the work of the borer is modified by the hardness or otherwise of the layers of the wood. It would seem that a portion of each ring of the tree's annual growth offers greater facility for excavation than the remainder, and thus the chambers shown in some cases measure over 1 in. across and long, but are often less than $\frac{1}{8}$ in. high, what may be termed the "floor" and "ceiling" being formed of the harder, and possibly less palatable, portions of two contiguous annual rings. No. 3 in the photograph shows portion of a kauri paling, of poor quality, from which a few shavings have been taken off with a plane, possibly between $\frac{1}{32}$ in. and $\frac{1}{16}$ in.: this illustration shows how close to the surface the larvae will work without breaking through.

SOME EXAMPLES I HAVE MET WITH.

I have observed the work of this borer principally in kauri and puriri, but have also seen it in blue-gum (live and dead wood), totara, *Pinus*

pinaster (live and dead wood), the gum commonly known as "Hobart Town," tea-tree, and other timbers, and am satisfied that there is practically no building-timber it will not take to when opportunity offers. One of the earliest instances I saw was in the large old kauri-built Government Buildings at Tauranga (since burned down, in 1903), the insects having attacked a matched and varnished dado put in some three or four years previous to my discovery. The method of discovery was simple. Casually resting one hand against the dado, the point of my thumb broke through the thin veneer left by the insect over one of its larger cavities, and considerable and surprising revelations followed.

Other instances which linger in my memory are of the felling of a fair-sized blue-gum which appeared to be dying, and parts of which were found to be riddled with white ants; of the felling of a *Pinus pinaster* and finding a dead branch literally alive with the ant, while—more surprising still—though the live portion of the tree adjoining was heavily charged with turpentine (for which oil this variety of pine is largely grown), it also was rapidly falling a prey to the ant. When directing repairs to a timber wharf some twelve years ago, wherein the piles were of totara and the other timbers of kauri, the ant was found in numbers, and in the top of one of the piles we found a cavity as big as a bucket, from which the ants could literally be scooped out with a spoon.

By far the most serious instance, however, which it has fallen to my lot to discover was in a bridge-truss, having a span of 60 ft., which I examined some fifteen years ago. Here I found a very large and active colony of ants at work at the bottom chord of the truss, right at the seat of the last diagonal strut at one end—about the most vital spot in the whole structure.

Called upon to report upon the foundations of a large two-story wooden hotel built entirely on puriri blocks, many standing 4 ft. and 5 ft. out of the ground, I found some of them had crumbled to dust under the attentions of the ant, which had also spread in some places to the plates and joists. One block gave a startling demonstration of the powers of our white ant, it having apparently been the butt of a small puriri, or else a stout straight branch some 8 in. in diameter, with the bark left on. Revealed by the dim light of a lantern, it stood nearly as high as my head under a runner, and at first sight looked to be doing its full duty still. A testing blow with the head of a tomahawk, however, sent it flying, and it lay revealed as an empty pipe of bark from which the ants had removed every vestige of timber.

In conclusion, there is one feature of the methods of this dangerous pest which I think is somewhat unusual in its class, and that is that it may invade a piece of timber at some point, and, having worked sufficiently to very materially reduce its strength for perhaps a length of a foot or two, it will leave it entirely—a very annoying experience if the timber happens to be an important stringer or chord of heavy section and perhaps 40 ft. or 50 ft. long. Nevertheless, though the strength of the member may have been thus reduced by half, or more, all that this insidious foe may leave on the surface to indicate what it has been doing may be a very few pin-holes, widely scattered, and which a grain of sand or a few specks of dirt would readily mask or obliterate.

SPHAEROBOLUS STELLATUS TODE.

A Fungus with a Remarkable Method of Spore-dissemination.

By G. H. CUNNINGHAM, Biological Laboratory, Wellington.

THIS species is a saprophyte, growing on dead wood, manure, old sacking, or on the ground. The fructifications are quite small, large forms seldom attaining a greater diameter than 2 mm. In structure they consist of a more or less globose peridium, arising from a mycelial weft which covers the surface of the substratum. The nearly mature peridium is somewhat complex, consisting of (*a*) an outermost layer of loosely woven hyphal filaments undifferentiated from the mycelium covering the substratum (fig. 1, *a*); (*b*) a pseudoparenchyma of closely woven, partly gelatinized hyphae (fig. 1, *b*): these two layers collectively constitute the exoperidium, which encloses (*c*) a layer of hyphal filaments arranged in a more or less parallel manner (fig. 1, *c*); and (*d*) a layer of elongated cells arranged in columnar fashion, with their long axes at right angles to the surface of the peridium (fig. 1, *d*). These cells are rather large in size; they are closely compacted together, and form the endoperidium, surrounding a central cavity within which is situated the globose peridiolum* containing the gleba.

In structure the peridiolum consists of an outer pseudoparenchyma of closely woven, partly gelatinized hyphae, surrounding a central mass. At first this central mass consists of loosely woven hyphae, which later become somewhat compacted; then several cavities, separated by thin walls (trama), make their appearance. The inner surfaces of these cavities are lined with the hymenium, consisting of paraphyses and clavate basidia. The spores are sessile, sterigmata being absent, and range in number from four to seven on each basidium.

Finally the basidia and tramal walls become gelatinized, so that at maturity the central mass of the peridiolum consists entirely of spores embedded in a gelatinous matrix. A few peripheral hyphae do not become gelatinized, but are later converted into gemmae.

As the peridium approaches maturity it enlarges in size, and gradually grows through the enveloping layer of hyphae (fig. 1, *a*, and fig. 3) until the apex becomes exposed; this then splits in a stellate manner (by unequal pressure created by the continued growth of the apical portion of the endoperidium) and exposes the enclosed peridiolum. The endoperidium continues to develop until it separates from the exoperidium, rupture occurring along the layer of parallel filaments (fig. 1, *c*), which have at this stage become somewhat gelatinized. Suddenly the endoperidium becomes everted, and stands above the exoperidium (fig. 4), the peridiolum at the same time being thrust out and thrown to some little distance (fig. 5). The endoperidium does not become separated from the exoperidium when eversion occurs, but remains attached by the apices of the rays. The mature gleba is externally somewhat viscid, so that it readily adheres to any object with which it may come in contact.

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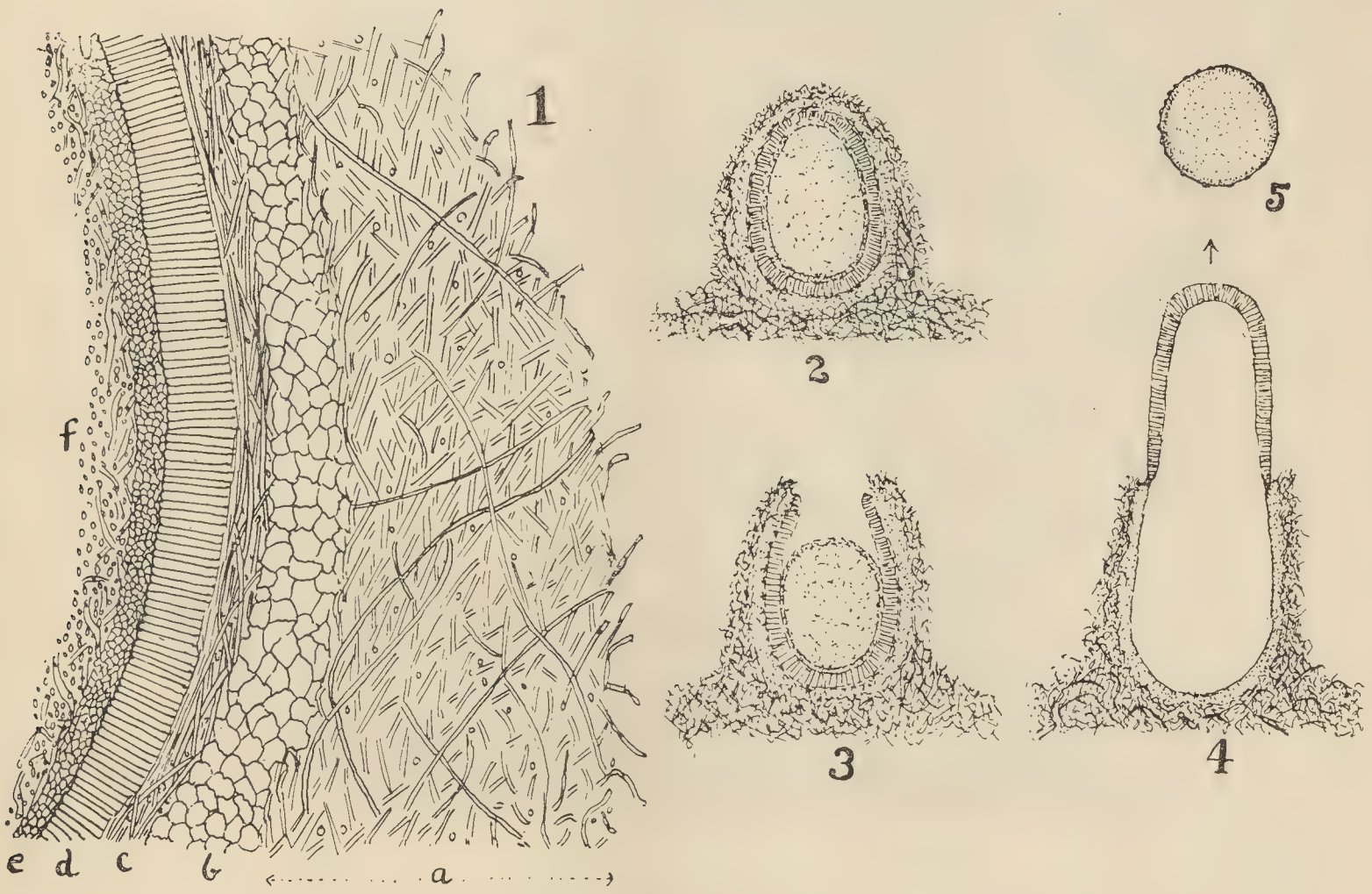
* This structure is so generally termed the "peridiolum" that this name is retained here; structurally, it is quite different from the peridiola of the Nidulariales, and should therefore be distinguished by some other and more suitable term.

I have had this species growing on rotting sacking in the laboratory for several months; it is contained within a large flask, and the interior of the flask has in several places become covered with numerous peridiola which have adhered to the glass; in some instances these peridiola have been thrown to a distance of 100 mm. Generally, eversion of the endoperidium occurs suddenly; sometimes, however, the process is a gradual one, when the peridiolum is carried to the apex of the everted endoperidium, where it may remain or else fall to the ground.

Under favourable conditions the peridiolum quickly gives rise to a copious mycelium, which, according to Fischer (1884), arises as a result of the germination of the gemmae contained within the peridiolum, and



Sphaerobolus stellatus.

FIG. 1.—Section through the wall of the peridium; × 45 diam. *a*, Outermost layer of loosely woven hyphal filaments; *b*, pseudoparenchyma of closely woven, partly gelatinized hyphae; *c*, hyphal filaments arranged in a parallel layer; *d*, elongated hyphal cells arranged in columnar fashion; *e*, wall of peridiolum showing the few hyphae which later become converted into gemmae; *f*, basidiospores embedded in the gelatinous matrix.
FIG. 2.—Mature peridium, immediately before dehiscence; × 8.
FIG. 3.—Peridium splitting at apex; commencement of dehiscence; × 8.
FIG. 4.—Peridium with everted endoperidium; end of dehiscence; × 8.
FIG. 5.—Peridiolum ejected from peridium as the result of dehiscence; × 8.
Camera-lucida drawings. Original.

not, as might be expected, from the basidiospores, which apparently germinate but rarely, and appear commonly to undergo gelatinization in a manner similar to the tramal walls.

This genus was at one time included in the Nidulariaceae, as it was believed that the peridiolum was similar in structure to the peridiola of this family. Microscopic examination shows it to be quite distinct, however, as has been shown above; and because of this distinction, and the fact that the peridiolum is solitary within the peridium, Fischer (1900) placed it in the Sphaerobolaceae, a family he erected for the purpose. The family contains the single genus *Sphaerobolus*, which, according to

Fischer (1900), contains five species; but it appears to be doubtful whether more than one species is found in nature.

SPHAEROBOLUS Tode.

Tode, *Fung. Meckl.*, vol. 1, p. 43, 1790. *Ex* Pers., *Syn. Meth. Fung.*, p. 115, 1801. *Carpobolus* Mich., *Nov. Pl. Gen.*, p. 221, 1729.

Peridium sessile, on a mycelial weft, fleshy; consisting of a two-layered exoperidium, enclosing a somewhat thick endoperidium. *Peridiolum* solitary,

[*E. Bruce Levy, photo.*

Sphaerobolus stellatus.

FIG. 6.—Peridia growing on decaying sacking, × 5. At the top left hand are shown immature peridia; below is a peridium at stage of fig. 3 (see arrow); in the centre is a group of six peridia with everted endoperidia, the condition shown in text-fig. 4.

globose, at first enclosed within the endoperidium, becoming extruded by the sudden eversion of the endoperidium. *Basidiospores* hyaline, binucleate, enclosed within the peridiolum.

Distribution—World-wide.

The genus is characterized by the structure of the peridium, solitary peridiolum, and peculiar mode of dehiscence.

Sphaerobolus stellatus Tode, *l.c.*, p. 45. *Ex* Pers., *l.c.* (Figs. 1–6.)

Sphaerobolus tubulosus Fr., *Syst. Myc.*, vol. 2, p. 309, 1822. *S. stercorarius* Fr., *l.c.*, p. 310. *Carpobolus cyclophorus* Desm., *Rec. Trav. Soc. Lille*, p. 225, 1823. *Sphaerobolus cyclophorus* (Desm.) Fr., *Elench.*, vol. 2, p. 52, 1828. *S. impatiens* Boud. in Bisch. *Kryptogamen.*, t. 3644 (?), 1860. *Carpobolus stellatus* (With.) W. G. Sm., *Jour. Bot.*, p. 280, 1903.

Peridium sessile, at first embedded in the mycelial weft covering the substratum, becoming somewhat erumpent, subglobose, and up to 2 mm. diam., fleshy, externally hirsute and dingy-white, internally smooth and

orange. *Peridiolum* solitary, globose, reddish-brown, 0·75–1·25 mm. diam., lenticular when dry. *Basidiospores* hyaline, continuous, globose or obovate, 6–10 × 5–8 μ; epispore smooth, 2 μ thick, cell-contents granular.

Habitat.—Crowded on decaying wood and leaves, old sacking, manure, and on the ground.

Distribution.—World-wide. On rotting wood and sticks lying on the forest-floor, Ohau River, Wellington, 100 m., *E. H. Atkinson*, 12/9/19. On rotting sacking, decaying wood, and on the ground, Kelburn, Wellington, 125 m., *G. H. C.*, 27/6/22.

The plant varies considerably according to the substratum upon which it may happen to be growing; judging from the published descriptions, it would appear as if several species have been based on these variations. I have collected this species from various substrata, all within an area of one square metre, and although the external form differs somewhat according to the substratum, yet microscopic examination shows that in structural details all are identical.

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RISSO'S DOLPHIN *(GRAMPUS GRISEUS).*

By Professor W. B. BENHAM, Otago University, Dunedin.

MR. OLIVER, in his "Notes on the Whales and Dolphins of New Zealand," mentions that, at the time he wrote, this species was represented in this country solely by a lower jaw in the Dominion Museum. About a couple of weeks after receiving that number of the *Journal** a mandible of this dolphin, which had been dug up near Anderson's Bay, Dunedin, during the formation of a drain, was presented to the Otago University Museum by Dr. R. Fulton, who informed me that it was found under about 10 ft. of soil. The mandible is undoubtedly that of Risso's dolphin, which is characterized by the presence of four teeth close to the symphysis. These sockets are shallow, rounded, and close together, indicating short-rooted teeth, which I suspect readily drop out. The length of the jaw is 17 in., which is longer by 2 in. than that in the Dominion Museum. The symphysis is $2\frac{1}{4}$ in. in length, and the alveolar length is $2\frac{1}{2}$ in. The individual sockets vary somewhat in width: the second is the largest, with a transverse diameter of $\frac{3}{4}$ in.; the first and last are but $\frac{5}{8}$ in. across. Their depth is $\frac{1}{2}$ in., with a rounded bottom, separated from one another by very narrow bony septa.

I hoped that other portions of the skeleton might be found in the neighbourhood, but my inquiries were met with a negative: the mandible was the only bone found.

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RECENT ENGINEERING DEVELOPMENTS IN WESTERN INDIA.

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IN order to appreciate the extensive and varied developments which have taken place in Western India in recent years, it is necessary to realize that the City of Bombay, in addition to being the centre of the Bombay Presidency and the outlet for a large area of rich country, is also the gateway of India. More than half of the foreign trade of India passes through Bombay, and it is the natural port for all speedy communication with the west. The population of the city itself is well over a million, and this population, almost equal to that of the whole of New Zealand, is concentrated in an area of about four miles by two and a half miles. The reason of this concentration of population on so small an area is partly geographical and partly economic. The business centre of Bombay is in the vicinity of the Victoria Terminus of the Great Indian Peninsular Railway and of the Alexandra Docks, in the south end of the island, where the total width of the city is only about half a mile. This in itself results in congestion, and the cotton-mills, which represent the chief industrial feature of Bombay, are only two or three miles farther north, where communication with the docks, the railways, and the "Cotton Green," where sales of raw cotton take place, is easy. The Indian labourer has few wants and receives low pay, and he lives near his work for two reasons—first, that he does not mind congestion and has always been accustomed to live ten in a room, and, secondly, that his economic position does not permit him to make use of mechanical means of transport, however cheaply these may be provided. Wages for coolies are now about 10 or 12 annas (*i.e.*, pence) a day, so that they are obliged to walk to their work, and must live near to it. The Government has been doing its best to make millowners realize their responsibilities to their workers, but progress is slow in the meantime.

DOCKS.

This outline of the conditions prevailing will indicate that shipping facilities form a very important item in the engineering developments in the city, and I shall begin by outlining briefly what has been done in recent years. And here let me mention that I intend to confine myself to works executed in whole or in part during the past ten years, and that the works described in this paper, with one exception, have never been described in technical papers before, so far as I am aware. For dimensions and details I must rely largely upon my memory of the works and partly upon notes in my possession, and in order to give a general idea of the scope of the works in progress I must pass lightly over many interesting details.

A very extensive addition has been made to the dock accommodation of Bombay during the past ten years, in the construction of the Alexandra Docks, shown in fig. 1. These docks accommodate about twenty vessels of the largest sea-going type, and provide all the most modern facilities

for handling the ships and their cargoes. The Peninsular and Oriental Company is building at present liners of 20,000 tons for the Eastern and Australian trade, and these, with all grades of smaller ocean-going steamers, can be accommodated. The quay-walls are granite-faced, and are provided with extensive reinforced-concrete sheds and warehouses of two stories, served by hydraulic cranes, lifts, and capstans. An entrance lock secures a constant water-level within the dock, and the lock-gates are also operated by hydraulic cylinders. The lock is spanned at one end by a roller lift bridge, electrically operated. A dry dock to take the largest vessels is provided, with a division at half its length so that two vessels of moderate size may be accommodated simultaneously, extensive repairs being dealt with in the inner dock, while other vessels may use the outer dock for smaller repairs successively without in any way interfering with the work proceeding in the inner dock.

A very extensive railway system of sidings serves the docks, and connects with both the main railway systems which run into Bombay. Outside the entrance lock the granite quay-wall is prolonged to provide a berth for the Peninsular and Oriental mail-steamers which run weekly to and from England. Opposite this berth a handsome granite building of two stories forms a terminal station for the mail-trains to Delhi and the north, to Calcutta and Bengal, and to Madras and the south. Facilities are provided for handling mails and passengers' luggage, and for Customs examination, while passengers find refreshments, postal and telegraph conveniences, and all else they are likely to require.

Bombay Harbour itself provides a commodious and safe anchorage for all sea-going vessels, and, indeed, it is the only really good natural harbour on the Indian coast-line, so that the provision of the most up-to-date accommodation makes it one of the foremost ports in the world.

Municipal.

To turn now to the municipal activities of the city, these are so varied that it is difficult to know where to begin; but it may almost be said that Bombay has been completely rebuilt in the past fifteen years. To begin with the municipality itself, this body has undertaken a very extensive system of town-planning in recent years. The old streets, flanked by three- and four-story houses of brick nogging or concrete, formed a maze of crooked lanes and alleyways. The building-material was usually a poor quality of brick, or of concrete made from badly prepared lime mortar and rounded shingle, combined with a framework of badly fitted teak. The result was a series of accidents in which houses collapsed, killing the occupants. The municipality uses its powers under the Town-planning Act to rectify this state of things, the method of procedure being as follows:—

When it is decided to renovate a block of the city, plans are prepared by the City Engineer showing the proposed arrangement of new streets: these are straight, and of sufficient width for modern traffic, and are so arranged as to fit in with the general scheme proposed for the surrounding areas. The plans are published along with the declaration that the land is to be taken up for town-planning, so that owners will profit by any enhancement of values which results from the change. The municipality then acquires the land required for the new streets, and clears it of buildings; the owners are compensated by being given equal areas from

the old abandoned streets, which usually occupy as large an area as the new ones, though narrow and crooked. Monetary compensation may be given in some cases, but a well-thought-out scheme will avoid this; it is not always necessary to give an owner an equal area in compensation, as a frontage on the new main streets may be much more valuable than a larger area before the change.

The value of the land always rises sharply as a result of the improvements, and the municipality is more than compensated for the outlay on new roads, sanitation, &c., by the enhanced rates resulting from the increase in land-values. So that the arrangement is profitable to all concerned; and, though some opposition was at first met with, there is now keen purchasing of land in an area likely to be taken up for town-planning.

THE IMPROVEMENT TRUST.

To turn now to another body which is responsible for the improvement of the city, but which is independent of the municipality, I will outline the method of operation of the Improvement Trust. This body acts under the authority of Government as an independent organization, and began operations on capital provided by a Government loan, which I believe in the first instance amounted to about Rs. 40 lakhs (*i.e.*, £266,000). The Trust buys up waste land in and around the city, puts roads through it provided with water-mains, sewers, &c., and sells it as building-plots, on certain conditions; the buildings erected on these plots have to satisfy the Trust's architects as regards size, appearance, sanitation, and stability, and to conform to the municipal regulations as regards light and air, and they must be built within two years of purchase of the land. The enhancement of the land-values resulting from the improvements provides a good profit on the whole scheme, so that the capital is recovered for further improvements and interest is paid on the original loan. In some cases additional loans have been obtained to supplement the capital in hand, but in most cases the original loan, together with profits over and above payments of interest, have sufficed for new schemes. The result of the operations of the Trust can be seen on all sides in Bombay: land which was entirely waste, dotted with palm-trees, ten years ago is now occupied by substantial blocks of residential flats and handsome shops, facing asphalted roads, with shade trees in the side streets, and, in fact, with all the air of a long-established and prosperous part of the city.

I will give but one instance of the operations of the Trust in detail, and select for this purpose the scheme on which their energies are at present chiefly concentrated. In the north-west corner of the Island of Bombay, just south of Mahim Bay, a new residential area is being created, as shown in fig. 1. A bay on the sea-front is being filled in, a substantial hill levelled, and a swamp filled up. The material used in the filling is obtained by levelling one of the small hills which are to be found dotted about the island; these hills are rapidly being demolished for the purpose of providing filling, and only the two hills supporting service reservoirs, and the residential areas of Malabar and Colaba Hills, will remain in a few years' time. The hill now being demolished is, I should say from memory, about three-quarters of a mile in length, 200 to 300 yards in average breadth, and about 150 ft. in height, and a low extension northward, shown in section in fig. 1, forms the backbone of the graded ridge which is to form the new residential area.

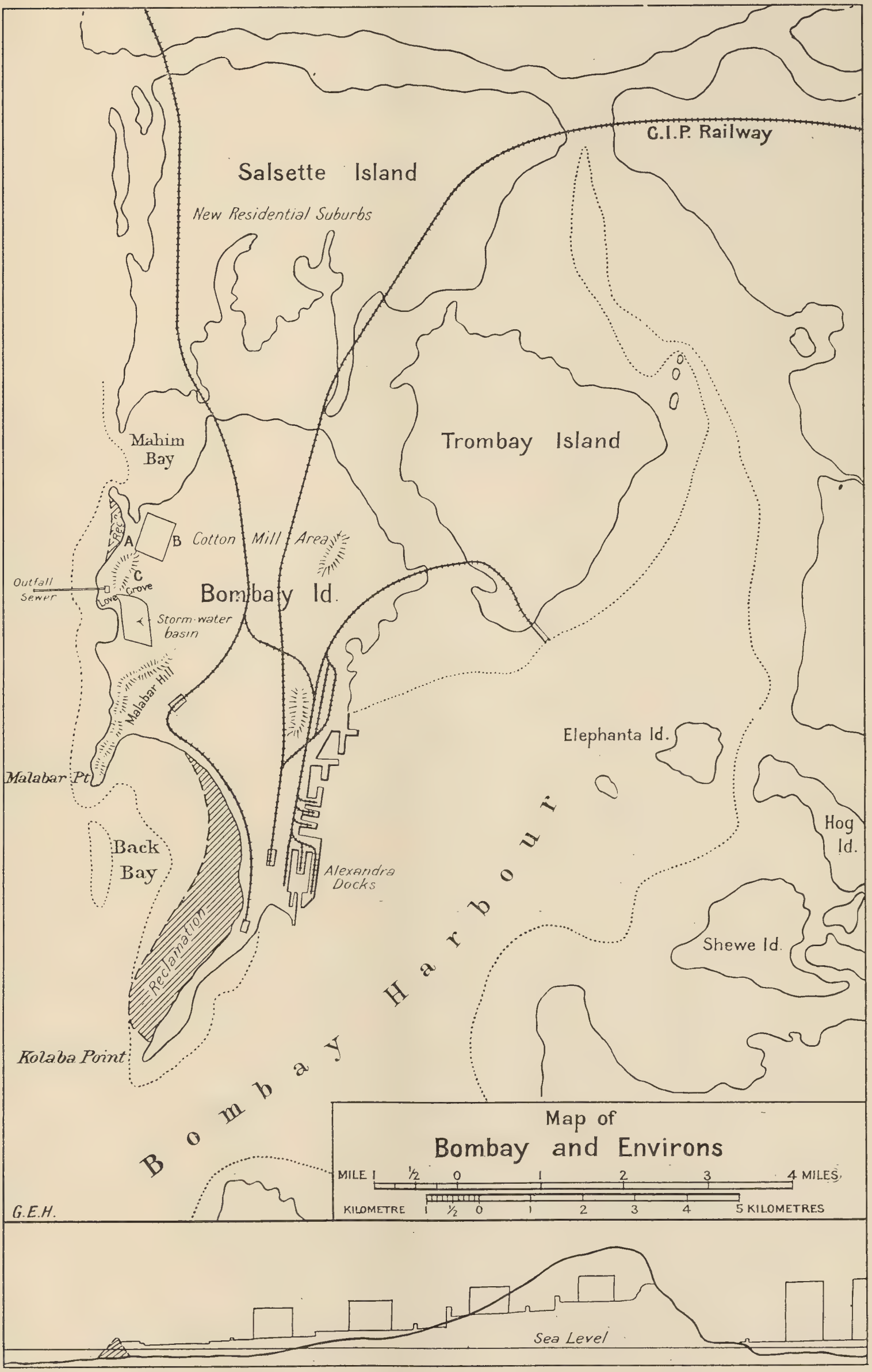
G.I.P. Railway
Salsette Island
New Residential Suburbs
Mahim Bay
Trombay Island
A
B
Cotton Mill Area
C
Grove
Outfall Sewer
Bombay Id.
Storm-water basin
Malabar Hill
Malabar Pt.
Back Bay
Alexandra Docks
Reclamation
Kolaba Point
Elephanta Id.
Hog Id.
Shewe Id.
Bombay Harbour
Map of
Bombay and Environs
MILE 1 ½ 0 1 2 3 4 MILES
KILOMETRE 1 ½ 0 1 2 3 4 5 KILOMETRES
G.E.H.
Sea Level

FIG. 1.

The hill consists of rock, rotten rock, and soft earth. The rock is blasted out and used for the sea-wall across the bay, which is being reclaimed, and for road-metal throughout the city. The rotten rock (known locally as *muram*) and soft earth are being excavated by several Bucyrus diggers of the most powerful type, and the material is conveyed by a service railway system of broad gauge (5 ft. 6 in.) with side-tip wagons. The slope facing the sea is arranged in steps. On the sea-front is a broad motoring road of asphalt laid on concrete foundation. Facing this is a row of fairly large compounds containing four-story blocks of flats. Behind these is a retaining-wall and a further series of compounds about 8 ft. above those of the front row, and provided with similar buildings. These are served by an asphalt road which runs behind them. Behind this again is a third row of similar flats at a still higher level, and so on. There are in all five such rows, and the buildings in each row are opposite the intervals of the row in front, while the whole series is designed on a gentle concave curve. There will be, therefore, a complete absence of formal severity, and the buildings in the rear will have a full share of the sea-breeze and the sea view. The upper stories in particular will have a clear view of the sea.

This part of the scheme will provide accommodation for the upper middle classes. But in rear of the slope above referred to lies a large area which is below the level of high tides, and close to the mill district, which lies immediately to the eastward of it. This low ground is also being filled in to a depth of 8 ft. to 10 ft., and on it are being constructed four-story *chawls* of reinforced concrete. A *chawl* is a block of buildings in which the labouring classes live, each family occupying one, two, or three rooms, in accordance with their means and customs, but more often than not one room. The scheme under discussion will provide 50,000 one-room tenements. Needless to say, it has been much criticized. It is bad enough that the economic conditions of the people should be such as we find them, but to actually provide in cold blood for the housing of 50,000 families in one room each is contrary to modern ideas of the fitness of things. The fact remains that a great proportion of the labouring classes in India do live in one-room tenements, and are quite content to do so; in a crowded city like Bombay it is a question whether to leave them in the swarming hovels in which they now live, devoid of light, air, or sanitation, or to provide for them well-built and rain-proof buildings with all these advantages. It has been shown that the economic position of the labourer will not allow of the provision of more rooms per family, and it is very doubtful indeed whether, if his economic position were improved, he would spend his increased earnings on better housing. The tenements referred to have been so designed, however, that the rooms may be combined to form two- or three-roomed houses if required. The cost of this whole scheme will be about £1,300,000, and it is scheme No. 56 of the Improvement Trust, which will give some indication of the magnitude of the works going on within the City of Bombay.

DEVELOPMENT DIRECTORATE.

Nor are the municipality and the Improvement Trust the only bodies charged with the improvement of the city; I must refer also, though very briefly, to the newly formed Development Directorate, which is extending the residential and business area of the city in more than one

direction. It is working on the basis of a public loan of about £4,300,000, and is developing the Island of Salsette as a residential suburb, which is to be served by fast electric trains, while at the same time it is reclaiming a large part of Back Bay, in order to provide building-sites near the narrow and crowded business centre. A sea-wall is now being built to enclose this area, and it is to be filled in by sand-pump discharging across the island from the harbour. In connection with the Salsette development I recently tested a number of building-stones from the island, one of which crushed at 3,750 tons per square foot—the highest test result for stone of which I have been able to find any record.

Drainage.

The drainage of Bombay presents a difficult problem, in that a large part of the island is very low-lying, and quite extensive parts of the city are actually below the level of high spring tides. Combined with this feature is the fact that the rainfall is 90 in. in about four months, the bulk of this fall taking place during June, July, and August. I remember one fall of 12 in. in nine hours some years ago, and, though this was very exceptional, an inch an hour and more may be expected to continue for several hours at any time during the monsoon. During high tides the great volume of storm-water cannot get away, and the present arrangement takes advantage of a low-lying area behind an embankment into which this water may run temporarily, flood-gates allowing it to escape when the tide falls; the area thus acts as a kind of service reservoir for the storage of storm-water. The policy now followed, however, is to raise the level of all low areas which are taken up for improvement, so that there will be a natural fall to the sea at all times.

The sewage is dealt with in the normal manner, but there are some interesting features in connection with it. The outfall is at Love Grove (shown in fig. 1), and, as the distance from Kolaba Point is great, the sewage from that area is raised on the Shone system by compressed air into the main sewers, which discharge by gravity to Love Grove pumping-station. There the whole of the sewage is pumped to an outfall sewer which runs about three-quarters of a mile out to sea. The Love Grove pumping-station and outfall sewer is the one outstanding failure among the engineering undertakings of Bombay, and some of us quite anticipated that it would be so. The sewer consists of two mains, 8 ft. 6 in. in diameter, made of $\frac{5}{8}$ in. steel plate with pneumatic riveted joints, and embedded in mass concrete. On either side and between the mains are walls of moulded concrete blocks which form part of the finished structure and serve as shuttering for the mass concrete round the pipes. The sea-bed is shallow and rocky, and the sewer has been laid on the surface, which was smoothed off for the purpose. The result is that the discharge is deflected shorewards by the coastal currents eddying round the end of the obstruction, and may be smelt several miles away when there is a sea-breeze. The pumping-station contains plunger-pumps of the beam-engine type, which are no doubt very economical when judged on the indicated horse-power; but there are several hundred small flap valves on the suction and delivery sides which have given great trouble by coming off, and must cause a great loss in pumping efficiency. A bucketful of detached valves is taken out every few days and new ones fitted.

The sewage problem in Bombay is therefore acute, and will have to be dealt with by a different method at an early date; several proposals have been put forward, but no definite action has yet been taken in the matter. The present outfall sewer cost about £250,000.

RAILWAYS.

To take next the railway development in the vicinity of Bombay, it will be seen from fig. 1 that two railway systems terminate in Bombay, both on the broad gauge (5 ft. 6 in.). The Bombay, Baroda, and Central Indian Railway runs north along the coast, and, as the coastal strip is flat, there are no heavy works other than the bridges required to span the numerous tidal creeks which run into the sea. These creeks, however, present a serious difficulty, as they vary in width from a quarter to three-quarters of a mile and there is no foundation but soft mud. They are all built on screw piles, and the total length of bridge on this line amounts to many miles; speaking from memory, I think it amounts to about sixteen miles. The weight of locomotives on the Indian railways, as elsewhere, has been steadily rising, and this railway has been handicapped for some time by the limit of strength of its bridges. These bridges are now all being strengthened or renewed to take the standard goods-engines of 129 tons weight, or the even larger ten coupled locomotives which are now being used on the Great Indian Peninsular Railway.

The Great Indian Peninsular Railway is the other line running out of Bombay; it divides at Kalyan, the northern line running to Calcutta and the north, while the southern line runs across to Madras, and also connects with the narrow-gauge line running south from Poona to Bangalore and Mysore. I have not time to discuss the complicated gauge problem, which annually grows more difficult, but turn to the recent large works on the Great Indian Peninsular Railway. In the first place, the track from Bombay to Kalyan, a distance of forty miles, has recently been quadrupled, and the main shunting-yard is now at Kalyan, where there is a very extensive "hump" shunting-yard, in which a goods-train of forty wagons can be split up and sorted out in from fifteen to twenty minutes. The wagons are pushed slowly over the hump after being uncoupled, and run by gravity to their proper destination. The process is not without certain practical difficulties, but the chief requirement for successful working is to maintain the brakes in proper adjustment. If, owing to slackness or wear, the brake-block touches the wheel, however lightly, it is found that the wagons attain different speeds, and fouling occurs before they reach their proper sidings. A gang of fitters at the entrance of the yard passes all wagons through its hands, inspecting brakes and adjusting them where necessary, and this eliminates trouble in the yard and is beneficial from other points of view.

During the quadrupling of the line from Bombay a tunnel was driven through a rocky hill at Thana to avoid a diversion followed by the old alignment. The hill is of solid basalt, with vertical cliffs on either side, and the tunnel was driven without lining. When traffic commenced, however, the rock began to fall in in considerable masses, and gave such trouble that it has been necessary to stop traffic through it and line the tunnel throughout, a work which has just been completed. The difficulty was quite unexpected, for one could hardly find a more stable-looking

Map of Part of
Western Ghauts near Bombay
Showing
Water Power and Irrigation Reservoirs &c.
Scale
MILES 10 5 0 10 20 30 40 MILES
KILOMETRES 10 5 0 10 20 30 40 50 KILOMETRES
Bulsar
Daman
Western Ghauts
G.I.P. Railway
Irrigated
Area
Darna
Bhandardara
Kalyan
Electric
Transmission Line
BOMBAY
Bombay Harbour
Andhra
Kunti
Walwhan
Shirawta
Lonavla
Mulshi
Mula
Poona
Karakwaslar
KONKAN
Western
Bhatgar
Nira R.
Madras
Railway
Irrigated
Area
Koyna
— Diagrammatic Section of —
— Western Ghauts of Bombay —
40 miles
BOMBAY
300 ft
2000 ft
4000 ft
Sea Level
G.E.H.

FIG. 2.

type of rock; but the form of jointing in the interior of the hill caused the trouble.

Extensive regrading has been undertaken by the Great Indian Peninsular Railway on the northern line, but it presents no special features of interest. The chief engineering difficulty which has confronted the engineers of the Great Indian Peninsular Railway in times past has been the surmounting of the Western Ghauts. As will be seen from the section of the country given in fig. 2, the coastal strip is fairly level and forty miles in width, intersected here and there by precipitious ridges, which are offshoots from the main mass of the Western Ghauts. The country then rises by an almost vertical step of 2,000 ft. to the upland plain of the Deccan, which slopes away eastward towards the Madras coast. Thus the watershed of India in this neighbourhood is only forty miles from the west coast. Along the edge of the Deccan rise rocky ridges 2,000 ft. high, or 4,000 ft. above the sea, and on these there is an intense rainfall during the four monsoon months, June to September, owing to the saturated air of the south-west monsoon striking the steep barrier of the Ghauts. Both branches of the Great Indian Peninsular Railway have to surmount this rise of 2,000 ft. in order to reach the Deccan. The lines work up outlying spurs, the ruling grades being 1 in 35. Tank locomotives of special type handle the trains, one pulling and the other pushing. Recently a very heavy type has been introduced for this purpose; these are superheater tank engines of the 2–8–4 type. On both Ghauts there were, until recently, reversing-stations, but that on the northern line has recently been eliminated by a complete realignment, making fuller use of the ruling grade. It will be readily understood that this was a big undertaking, the work in such steep country involving numerous tunnels and very heavy earthworks. Viaducts have been avoided to a great extent, and embankments up to 120 ft. in height occur in places. Where viaducts exist they are of stone arches, thus eliminating upkeep charges and the future strengthening and replacement of girders.

It is proposed in the near future to electrify the Ghaut section of the northern line, a special hydro-electric scheme having been designed to supply current. The traffic on the southern line is not so heavy, and if this is electrified current will probably be taken from the hydro-electric-power supply companies in the vicinity.

It is also proposed to electrify the suburban railways near Bombay, and in the case of the Great Indian Peninsular Railway this change would extend forty miles to Kalyan Junction. Finally, it is proposed to construct a new terminal station for the Bombay, Baroda, and Central Indian Railway in Bombay at Grant Road, and to continue the service to the point of the island by an underground line.

HYDRO-ELECTRICS.

Perhaps the best-known engineering works carried out in the Bombay Presidency in recent years are the great hydro-electric schemes, some of which are running and others under construction or projected. The description which I have already given will indicate the possibilities which exist of hydro-electric development along the Western Ghauts. We have a vertical drop of nearly 2,000 ft. from the level of the Deccan to that of the Konkan, while along the watershed there is a rainfall varying from 450 in. on the high peaks to 100 in. in the valleys. In

addition, the valleys have comparatively little soft earth and soil, and present excellent rock foundations and flanks for dams, while stone for masonry abounds. Against all these natural advantages may be set the following drawbacks: The rainfall, though heavy, is badly distributed through the year: the great bulk of it takes place in the latter half of June, in July, and in August, while the heaviest rains are in June and July. The September rain may balance the draw-off, but from October till the following June the rain is practically nil, and the small streams which exist in the neighbourhood of the watershed are dry. Hence the water has to be stored in sufficient quantity to carry over eight dry months each year. Not only so, but in the event of a bad monsoon, when only half the normal rainfall may occur on the Ghauts, and the storage will be only partially replenished, it will be necessary to carry over the following eight dry months by drawing upon water previously stored. A further disadvantage is that the mouths of the valleys are often rather flat and wide, necessitating long dams. However, with 2,000 ft. of available head the value per cubic foot of the water stored is such that the advantages outweigh the disadvantages.

The first large scheme to be carried out was that of the Tata Hydro-electric Supply Company. This has been described in technical papers, and I will only refer to it briefly. There are at present three dams, known as the Lonavla, Walwhan, and Shirawta dams respectively. They are shown in fig, 2. All three supply the same pipe-line, Shirawta discharging into Walwhan, which happens to be a little lower, through the dividing ridge, by means of a tunnel a mile long, 14 ft. wide by 7 ft. high. It is driven in sound trap which needs no lining. Walwhan discharges into a duct four miles and a half long, which conveys the water across a low saddle in the Ghauts to the penstock. In the duct there are twenty-two aqueducts, three rock tunnels (1,160 ft.), and ten cut-and-cover tunnels. It is of rubble masonry with concrete-block sides and mass-concrete floor. This duct is joined at one point in its length by a branch duct, one-third of a mile in length, from Lonavla reservoir. The Lonavla reservoir is a small one, comparatively speaking, contained by a dam 26 ft. in height and over a mile in length; it is intended to maintain the supply during "breaks" in the monsoon, lasting two or three weeks, without drawing upon the main storage, which is filling up in preparation for the dry season. It also serves to delay the time when the main storage has to be tapped, by maintaining the supply for two or three weeks after the close of the monsoon. It contains 361,000,000 cubic feet.

Walwhan dam is 68 ft. in height above the bed of the valley and 4,500 ft. long, and contains about 2,560,000,000 cubic feet. Shirawta, at present the largest dam in the world as regards cubic content of masonry, is 92 ft. in height from the river-bed and a mile and a half (8,000 ft.) in length. It contains over 6,000,000 cubic feet of masonry, and gives a storage capacity of about 6,960,000,000 cubic feet of water. A fourth reservoir (Kunli) has now been commenced in the valley immediately north of Shirawta, and this will discharge into Shirawta by means of a duct round the nose of the hill, and will greatly increase the capacity of the scheme, to 120,000 horse-power.

The pipe-line is in two sections, the upper, 8,200 ft. long, being of steel pipes 6 ft. 10½ in. to 6 ft. in diameter, which convey the water down to a point just below the reversing-station of the Great Indian Peninsular

CONSTRUCTION OF NEW DAM, BHATGHAR IRRIGATION PROJECT.

FIG. 3.—Old and new dams. View from the future water-level at end of new dam: looking south. North waste weir of old dam discharging.

FIG. 4.—Old and new dams: looking north. The north waste weir discharging through openings left in new dam.

CONSTRUCTION OF NEW DAM, BHATGHAR IRRIGATION PROJECT.

Fig. 5.—Old dam with water at F.S.L.; and semicircular masonry coffer-dam at intersection of old and new dams: looking north.

Fig. 6.—Work in progress on new dam, showing type of masonry. Note the stones carried by coolie women.

Railway. So far there is only one of these pipes installed, but when the scheme is enlarged the other will be required, and all provision has been made for it. Below the reversing-station the pipe turns at right angles, and five pipes, each 4,800 ft. long, branch from it: they are 42 in. to 38 in. in diameter. These are welded steel pipes, and of course, like the upper section, increase in thickness and slightly decrease in diameter as they approach the power-house. The decrease in diameter allows of nesting the pipes one inside the other during transport. They are $1\frac{1}{4}$ in. thick at the power-house. Each of these pipes supplies an impulse-wheel of 11,000 horse-power, running at 300 revolutions per minute. The wheels are 12 ft. in diameter (9 ft. 6 in. on pitch line), and work under a head of 1,725 ft. The generators coupled to these turbines generate three-phase current at 5,000 volts, which is transformed up to 100,000 volts for transmission to Bombay; it is there transformed down to 5,000 volts again for use in driving the cotton-mills. The motors used are from 200 to 500 horse-power in most cases, each driving a whole room of spinning or weaving machines. The load is exceedingly steady during the working-hours of the mills, and the power is supplied to them at 0·55 anna a unit. (An anna is a penny.)

In view of the trouble experienced with insulators on high-tension lines in New Zealand, it may be of interest to mention that I have never heard of similar trouble in India, though the climate in the Konkan is very moist and hot. There was some doubt at first how a line carrying 100,000 volts would be affected by the monsoon weather, but the only trouble I have heard of is that an occasional vulture, with its wing-spread of 6 ft. or 8 ft., gets across the wires and shorts them. The wires are supported on steel towers. The phase spacing is 5 ft., and to earth 3 ft. There are now two lines, and eventually there will be four.

Andhra Valley.—A second and independent hydro-electric scheme has just come into operation; it is provided from storage in the Andhra Valley, which is immediately to the north of the Kunli reservoir, referred to previously. In this case the broad valley is intersected by a deep ravine, in which the river flows, and fortunately the broad valley-bottom itself rises into a transverse ridge about twelve miles from the head of the valley: by damming the ravine at this point a large storage capacity is obtained. The dam is 200 ft. in height from the river-bed, and 1,800 ft. in length. Like all the other dams in the district, it is a gravity dam of masonry; it is not provided with any sluices or openings, and the draw-off is through a tunnel from a point near the head of the ravine to the western side of the watershed. The tunnel is about two miles long, and is under a head of water of about 80 ft. The steel pipes leading down the cliffs to the power-house are sealed into the western end of this tunnel, and a branch tunnel rising on a steep grade to the face of the cliff above the outlet from the main tunnel acts as a surge-chamber. Only 80 ft. of water from the top of the reservoir can be drawn off, the remaining 120 ft. at the bottom being dead water, which cannot be tapped. As this lower portion is in the narrow ravine, its volume is not so great as would at first appear, the broad upper levels which are available containing about four-fifths of the total capacity. The lower portion will serve as a trap for silt. Scour-valves are not really of much value in clearing silt from a reservoir twelve miles in length—they only clear a small area near the dam; they are therefore entirely omitted, and there are no openings in the dam below the waste weir.

In this scheme the turbines are Pelton wheels made by the Pelton Wheel Company, and are each of 15,000 horse-power. At present four of these sets are in operation; two more will shortly be added, and a further extension of the scheme is contemplated. The generator is on the same shaft, the whole being on two bearings only. A good deal of trouble was at first experienced in the earlier scheme in aligning the four bearings of one of the sets, which settled slightly; and still greater trouble was experienced owing to the pole-pieces of the rotating-fields working loose. This trouble was very persistent, but has been overcome by an improved design.

Mula Mulshi.—Still another scheme of a similar type is being put in to the southward of those already mentioned; this is known as the Mula Mulshi scheme, the name being taken from that of the dam. The foundations of the dam are now being taken out, and the masonry work is under construction in places. A tunnel will be provided, much as at Andhra, and the scheme will provide 120,000 horse-power.

Koyna.—A fourth and much larger scheme has been surveyed, and will probably be undertaken shortly, farther south. This is the Koyna project for supplying 300,000 horse-power. The Koyna River is peculiar in that it flows south along the edge of the plateau for about twenty-five miles, following a rift in the hills, and then turns abruptly eastward through a narrow gorge. Its upper reaches are therefore all in the region of intense rainfall along the Ghauts, and by damming the gorge through which it breaks eastward an immense reservoir can be provided. The original proposal was to have one reservoir only, the dam being 350 ft. in height; but a more cautious plan is now to be followed, and there will be two dams, one at the gorge referred to and another ten or twelve miles up-stream, against the back of which the water of the lower reservoir will back up. As this would involve a loss of head if the water of the upper reservoir were allowed to flow into the lower one when required, there will now be two tunnels through the hill, two pipe-lines, and two power-houses; in fact, it will practically form two independent schemes. Both, however, will supply power for electro-chemical industries in a new industrial town which is to be created near the coast. A tidal creek will be developed into a harbour, and a branch of the Madras and Southern Maratha (metre gauge) Railway will be brought down the Ghauts to supply raw material, and also to act as an outlet to the sea for that railway system, which at present has to reach the sea at Bombay by transhipment to the broad-gauge line at Poona. There are considerable deposits of bauxite available in India, and the power will be used for the production of aluminium and for the fixation of nitrogen and similar purposes.

Irrigation.

I must not omit to mention the irrigation projects which are either in operation or in course of construction in Western India. These obtain their water from reservoirs much like those used for power purposes, and in similar positions, the difference being that they need not be in the immediate vicinity of the watershed. A number of such reservoirs already exist—*e.g.*, Darna, twelve miles in length and with a dam 60 ft. in height; Bhandardara, with a masonry dam of gravity section which holds up a clear depth of water of 270 ft. in a reservoir twelve miles long; Karak-waslar, the Poona water-supply, and one of the oldest of the irrigation schemes; Bhatghar, farther south; and others.

Bhatghar deserves more than passing reference. The original Bhatghar dam was built in the "eighties," and was 90 ft. in height and about three-quarters of a mile in length. It stored 4,800,000,000 cubic feet of water, and this was used to irrigate a stretch of country on the right bank of the Nira River. As usual in the Deccan, the water was allowed to find its way down the river-bed as required until, about twenty miles east of the reservoir, the country was sufficiently flat to permit of the convenient utilization of the water on the land. It was recently decided to enlarge Bhatghar storage and irrigate the left bank of the Nira also. This involved raising the dam to about 150 ft. in height, and, of course, it had also to be lengthened, though by no means in the same proportion. This work is now well in hand. The storage capacity will now exceed 25,000,000,000 cubic feet. Instead of raising the old dam, it was considered better, in view of the magnitude of the undertaking and the comparatively small volume of masonry in the old dam, to build an entirely new dam down-stream from the old one, so that the old one will soon be completely submerged. The power required for plant on the new dam is obtained from a small turbine-driven power-house drawing water from the old dam and discharging it down the river for irrigation. The four turbines, of 75 horse-power each, are by Escher Wyss, of the mixed-flow type, and work under a very varying head, dependent upon the amount of water remaining in the old reservoir. The new dam will be considerably the largest mass of masonry in the world, and thus take from Shirawta dam the pride of place which it now holds.

MASONRY.

Before closing, let me give you a few details regarding the type of masonry used in these great dams in Western India. It is all of one type, consisting of random rubble set in lime mortar. In New Zealand, and in Europe and America, mention of a masonry structure of any size immediately brings to the mind of an engineer a structure built in cement mortar; a proposal to build in lime mortar would immediately raise criticism and incredulity, and I confess that on first going to India I shared the general prejudice. A dozen years of observation of these great structures, and of experiment on the properties of lime mortar, has convinced me, however, that for a gravity section dam there is no better material. As every one knows, cracks invariably appear in a large mass of cement-concrete work; even in masonry set in cement mortar cracks are invariably present, though perhaps less conspicuous. Now, I have seen all the great dams mentioned above, some new and some fifty years old, and I have never yet seen a crack in any of them. It is true that during the first season in which they are subjected to water-pressure they "weep" and are somewhat porous, to an extent that might alarm the inexperienced; but this porosity invariably takes up by chemical action within the face of the dam, and they become thoroughly tight and reliable. The working stress now allowed in this type of masonry in large dams is 15 tons per square foot, and this proves perfectly safe, and I think might be increased without danger.

The lime used is of two types. In the Deccan there are large deposits of good hydraulic lime known as *kankar*, which may be picked up from the fields or quarried from shallow deposits. This lime has only to be burned in kilns, the fuel used being engine-ashes, poor-quality coal, or on small works wood or cowdung cakes. It is then slaked and afterwards

ground, along with the sand, for ten to fifteen minutes in large rotating pans under heavy rollers. River-sand being scarce, the sand is now usually made by crushing the trap-rock in roller crushers, and this product gives greater strength than river-sand. The proportions used are usually about 1 of lime to 2 of sand.

On large works it is sometimes difficult to obtain in the required quantity supplies of *kankar* hydraulic lime to which I have referred. In that case a fairly pure limestone is quarried and brought by rail from Bhagalkot, Shahabad, or elsewhere. This is burned as before. To render it hydraulic it is ground with *surki* as well as sand; *surki* is artificial pozzolana, and is in fact merely a poor quality of rather underburnt brick, which is prepared from any earth available on the site by a type of labourer who undertakes the work on contract, burning the brick in clamps fired with engine-ashes, wood, or cowdung cakes. The proportions used in the grinding-mill are about 1 of lime, 1 of *surki*, and $1\frac{1}{2}$ of sand. This makes a hydraulic mixture as good as that made of *kankar*, and more controllable in quality. It continues to gain in strength for a very long period. It has been systematically tested in the College of Engineering up to twenty-seven months, and still shows a steady gain of strength, which, however, proceeds less rapidly as time goes on. At the end of one month a strength of 20 to 30 tons per square foot is common; at three months, about double this strength; at nine months, about three times; and at twenty-seven months, four times the strength at one month. As the large masonry dams to which I have referred take a number of years to build, it is evident that the strength is ample for the requirements. It is not as great as that of cement, but, on the other hand, the material does not crack, is much less sensitive to careless handling, and continues to gain in strength indefinitely if kept moist, a condition fulfilled in large masses of masonry. It is also cheap in India, and, after grinding, it can be left for a day or two, or even for a week, without losing its setting properties, though of course the strength will in that case be somewhat reduced, and such delays are bad practice. Mixed mortar may be left overnight, however, without appreciably affecting its quality.

The stone used in the masonry is trap-rock, as heavy as possible, in order to give stability to the dam. The faces are often coursed rubble, the remainder being random undressed; each stone is no larger than a woman coolie can carry on her head to the required position. The proportion of mortar in the masonry is about 35 per cent., and this is kept low in order to increase the specific gravity of the whole. The stone is often obtainable of a density of 175 lb. to 180 lb. per cubic foot, and the finished masonry usually weighs over 160 lb. per cubic foot.

At Shirawta over 500,000 cubic feet of masonry was laid in a month on several occasions (= 18,000 cubic yards). I estimate roughly that the quantity of masonry in the dams to which I have referred is about 33,000,000 cubic feet (= 1,220,000 cubic yards). When small pieces of such masonry have had to be demolished it has been necessary to quarry them out with gelignite.

Sind Irrigation Project.

Finally, I can only mention by way of conclusion the largest engineering project at present contemplated anywhere in the world: this is the Sind irrigation project, which includes the construction of the Sukker barrage. It has been the subject of much controversy, particularly with reference to

the barrage itself, and no one who is not intimately acquainted with the conditions can give an opinion of value upon it. At present it appears that those in favour of the project will carry the day, and if money is forthcoming and political conditions remain stable it is likely to be undertaken almost immediately. The proposal is to construct a barrage across the Indus, in order to deflect its waters into the Rorhi and other canals which will water the greater part of the arid regions of Sind. One of the canals will be a quarter of a mile wide and 20 ft. or 30 ft. deep, and the cost of the whole scheme will run into about fifteen millions sterling.

I am sorry that I have not here available particulars of this huge scheme, of which Government has just disclosed the details. The Indus flows in the lower part of its course through great flat plains of fine alluvial silt, and, like other rivers on the Indian plains, often builds up its own bed and banks to a very appreciable height above the surrounding country. It then only requires one of the great floods which are not uncommon to cause it to burst through and change its course by perhaps five or ten miles. These facts, together with the consideration that there is no available foundation in the whole region other than sand and silt, will give some idea of the nature of the difficulties. However, there is little that the engineers of Northern India do not know regarding the handling of great rivers in beds of silt, and I have no doubt that the project, if undertaken, will be a success. The temptation to dip into the romantic story of engineering experiences on some of the northern rivers is great, but time will not permit me to go beyond the bounds of Western India; and, indeed, I have been able to attempt only a brief survey of a subject which would in itself fill a volume, hoping that in so doing I have given you some idea of the importance and variety of the developments in Bombay and the Bombay Presidency.

THE ECONOMIC HEIGHT OF A DAM.

By R. A. SUTHERLAND, A.C.G.I., B.Sc. (Eng.), London.

IN an article in August, 1921, in this *Journal*, A. D. Mead examined from a mathematical standpoint the question of the most economical size of a hydro-electric installation involving water-storage. The writer thinks that the following method of dealing with the problem may be of interest; although it contains necessarily some elements of an empirical nature, it will serve to bring into evidence the basis on which the solution depends, and thus lead to a clearer understanding of the question.

The economic size of an installation involving water-storage depends on each of the following factors: (1) Regularity or irregularity of flow of stream; (2) topographical features of site of impounding-reservoir; (3) type of dam proposed; (4) general lay-out of races, tunnels, &c.; (5) load-factor of plant.

The way in which these factors enter into the problem is in most cases obvious, as may be seen from the following considerations:—

1. A stream subject to excessive variations of flow will require a larger capacity of impounding-reservoir for its regulation than one in which the

flow does not vary greatly. The impounding-dam must therefore be larger, both to provide this storage volume and also to allow more reserve of depth for eventual silting-up, which is frequently troublesome with rivers liable to sudden "spates."

2. The ideal site for a storage reservoir is an extensive basin situated above a narrow gorge suitable for the erection of the dam. The more gentle the slope of the sides of the basin the more storage will be obtained for a given height of dam, and the cheaper the dam for a given storage.

3 and 4. The influence of these items on the cost is very largely determined by the topography of the locality. The presence of a narrow gorge flanked by solid rock, suitable for an arched dam, and of contours adapted for a short tunnel or canal, is obviously conducive to inexpensive

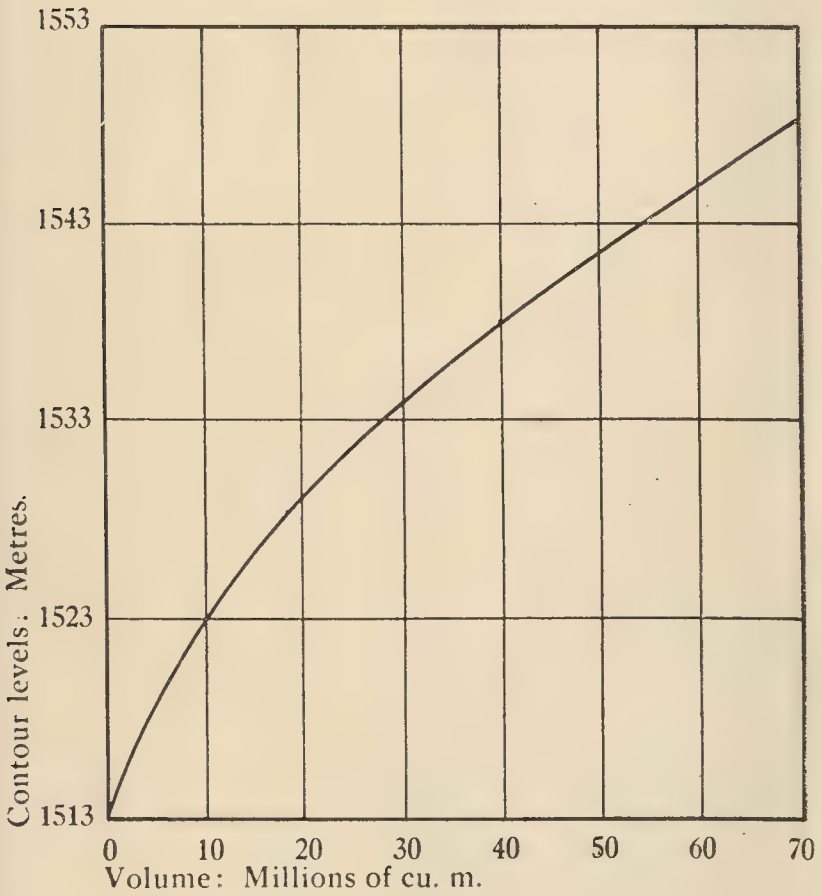

FIG. 1.

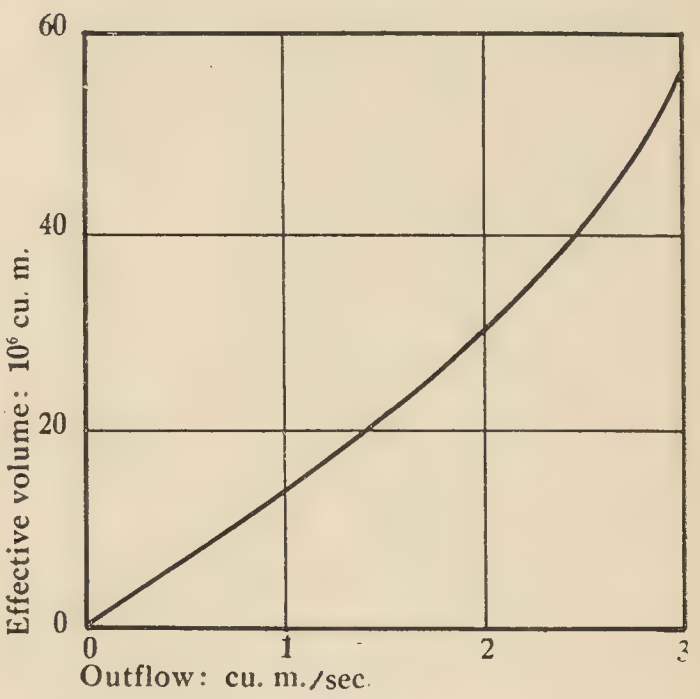

FIG. 2.

development, and *vice versa*. In the choice of lay-out more than anywhere else are the skill and experience of the engineer called into play.

5. The influence of the load factor on the cost of development is evident, although this influence is not by any means as simple as might at first appear. In addition to the obvious questions of reserve machinery, size of canal and pipe-lines, &c., attention must be paid to mean and maximum loss of head, necessity or otherwise of pondage, and regulation.

After the above preliminary glance at the question we propose to give graphs exemplifying for an actual case the points mentioned. These graphs relate to a proposed installation in Italy for the supply of lighting and power to a city.

The first step is the determination of the "mass curve" of flow of the river. This should be taken over a long period of years. From this curve can be found the volume required to be impounded in terms of the continuous regulated flow. Fig. 1 shows this relation for the case cited.

For the proposed reservoir-site we now plot the curve showing the relationship between volume impounded and contour level (fig. 2).

To find the height of dam required for any value of the continuous flow, we must first allow a certain depth to provide for eventual silting. The allowance made depends, of course, entirely on local circumstances, and must be decided case for case. In the present example the minimum level of water in reservoir was fixed at 10 metres above stream-bed, to give the best outflow-level and reduce the cost of pressure-tunnel. This level being fixed, we can at once find from figs. 1 and 2 the relation between total height of dam and continuous outflow.

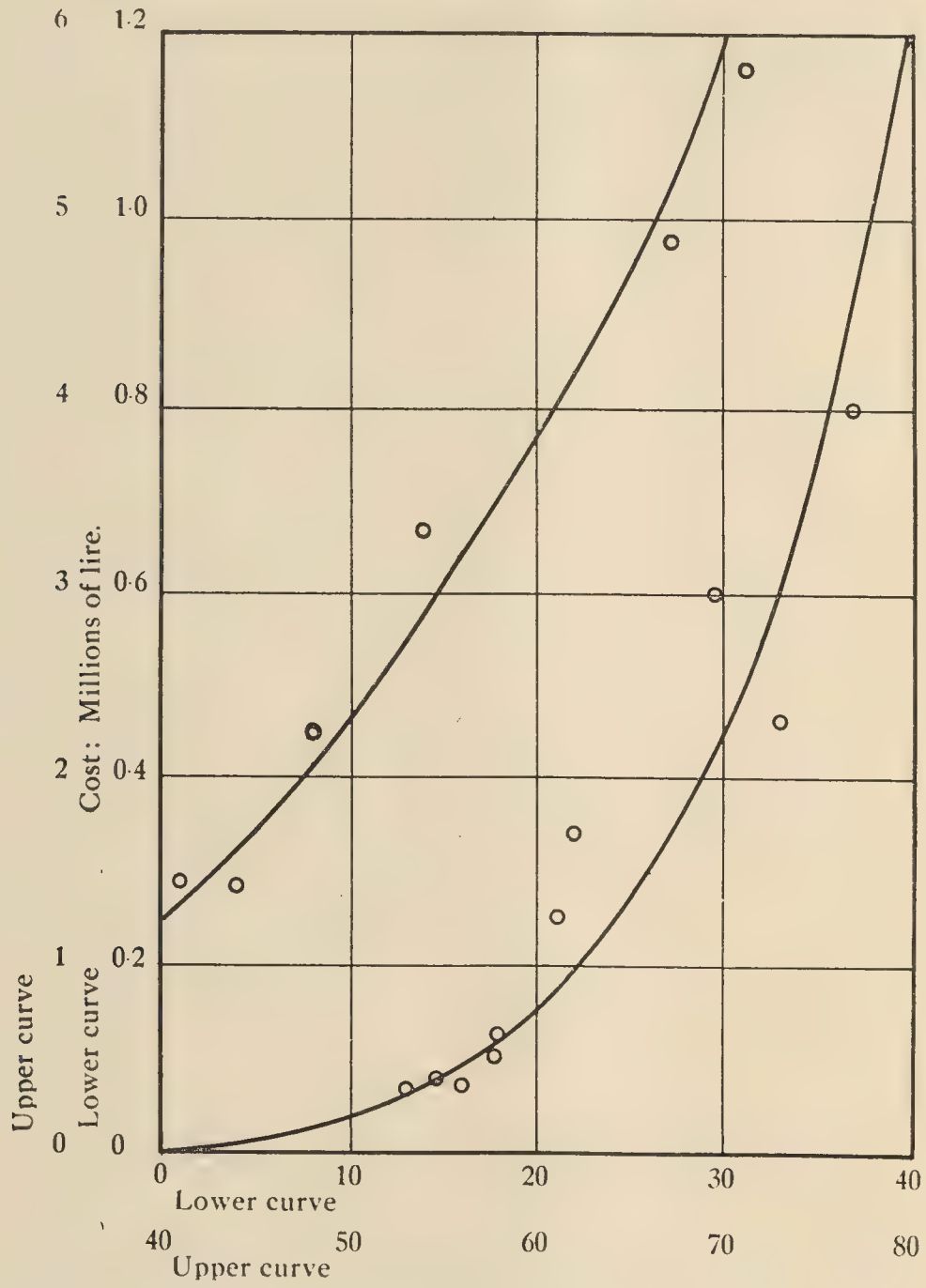

FIG. 3.

The type of dam is usually determined, or at least indicated, by the dam-site. In this case the multiple-arch type was adopted. From an analysis of the costs of sixteen similar dams of different sizes the curve shown in fig. 3 was plotted.

This gives the cost of a dam of this type in terms of its height. Since dams of the same height vary enormously in length, it is obviously necessary to reduce these costs to a common basis, assuming the width equal to the height in each case, and this has been done. It may be noted that the cost is not, at all events for the examples taken, proportional to the cube of the height, as would be indicated by purely theoretical considerations. This may be explained by the fact that with these dams a large part of the total cost consists of labour, the quantity of material

employed being usually about one-third of that required by a gravity dam of the same height.

Knowing the cross-section of dam-site, we can now plot the cost of dam in terms of the regulated outflow (fig. 4).

To find the cost of the canal, tunnel, and other water-conduits would involve a good deal of work in making up estimates for different values of the flow. In this case the cost has been assumed to consist of a fixed amount plus an amount proportional to the flow as shown in fig. 4. Hence for any value of the latter we can now find the cost of the installation up to the power-house. This total cost is shown in fig. 4. By

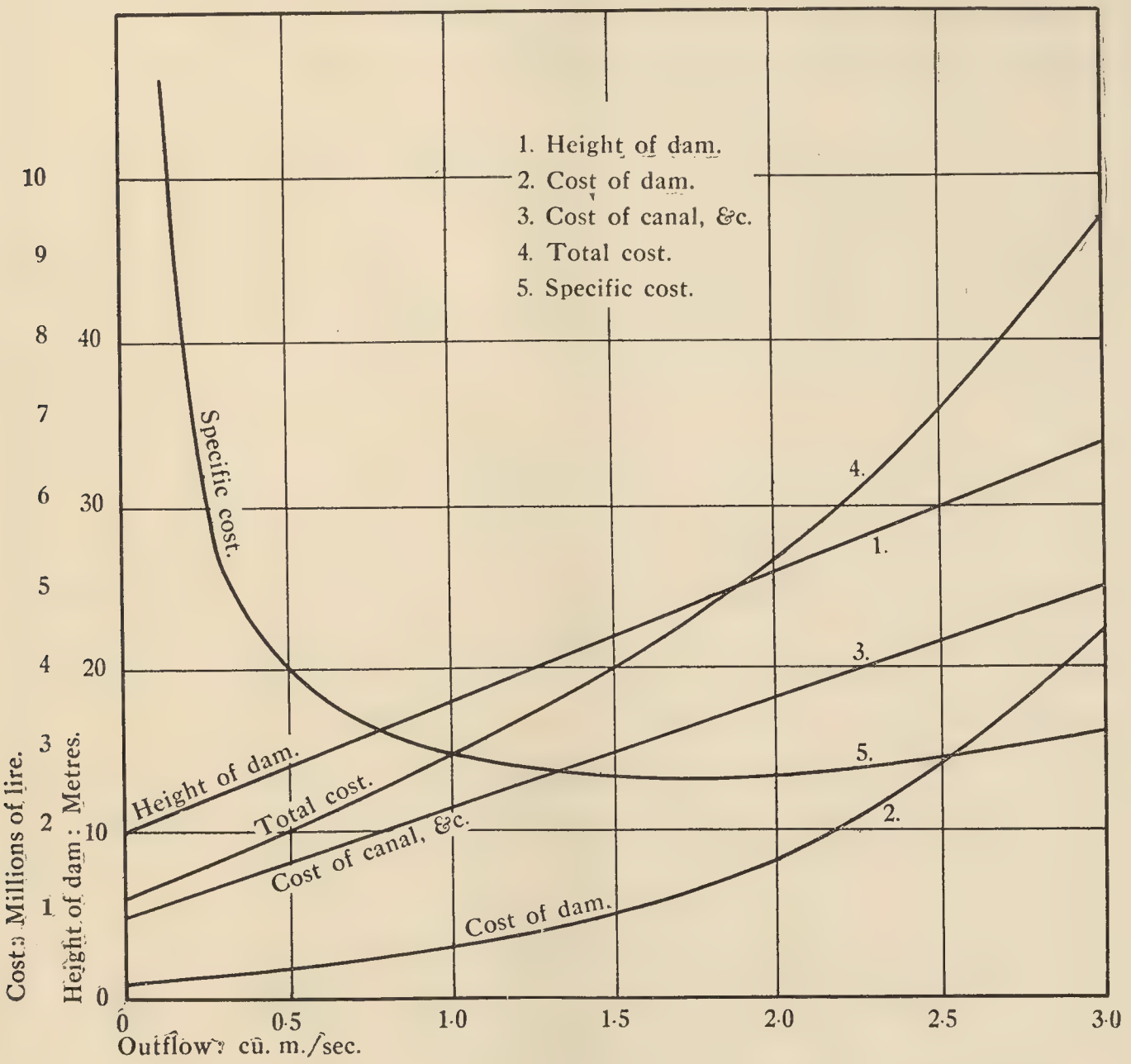

FIG. 4.

dividing each ordinate by the corresponding value of the flow we find the specific cost—*i.e.*, cost per unit of flow. With the cost of machinery, &c., we are not at present concerned. Curves giving the cost per K.V.A. of generators, transformers, &c., in terms of the power per unit are in common use, and the specific costs for these items, suitably modified for scale, can be added to those already found for the civil-engineering part of the work.

Fig. 4 shows plainly that for every scheme there is a certain development which will give the minimum specific cost, and this development should be aimed at. In some cases the specific cost will be found to have a very well defined minimum value; in others the value remains approximately constant over a certain range. Schemes which come under the latter heading are obviously more suitable for development by steps. There are, of course, many factors of an ecomonic nature which may alter entirely the aspect of any proposal, but these must be dealt with case for case.

THE INTRODUCED BIRDS OF NEW ZEALAND.*

By J. G. MYERS, R.A.O.U., Biological Laboratory, New Zealand Department of Agriculture, Wellington.

FOR the thorough-going efficiency with which he has delved into and analysed the scattered and uncoördinated records which constitute the earlier proceedings of the acclimatization societies in this Dominion the Hon. G. M. Thomson has earned the deepest gratitude of all present and future students of the birds now inhabiting New Zealand.

It is important to remember that, however much every ornithologist may deplore the ill-advised introduction of foreign species, such imported birds as have become thoroughly established are now ecologically part of the avifauna of the country, and as such are worthy of study for their own sakes, quite apart from any considerations of their relation to the indigenous birds, whose welfare should be the primary aim of every bird-lover in New Zealand.

Of the 130 species of foreign birds brought to New Zealand by private or official effort, only twenty-six have become thoroughly established in any considerable area. Of these, some, among which are numbered most of the more destructive species, are so nearly ubiquitous that their ultimate survival seems assured; while others are present in such small numbers, or inhabit such restricted areas, that were it not for fresh importations they would probably die out altogether.

In reading the account of the naturalized birds one is impressed by the mass of information presented, and by the care with which the authorities are stated. The notes I have to offer are chiefly of the nature of addenda.

The Chinese pheasant is now† recognized as only a race of the "English" pheasant, and should therefore be called *Phasianus colchicus* L. var. *torquatus* (Gm.). No expense has been spared to establish pheasants in this country. The wekas, or woodhens (*Gallirallus* spp.), were early recognized as the chief enemies of the eggs, and we read that in Canterbury, therefore, the acclimatizers "nearly extirpated the wekas." And this is the bird of which Guthrie-Smith writes, in view of its efficiency as a rat-destroyer, "If, then, in New Zealand any serious interest ever comes to be taken in our native birds, the most efficient method of preserving the smaller, tree-breeding species lies in the propagation of the weka. Of all the birds that deserve our care he comes foremost, and assistance withheld from him is help denied to half the indigenous birds of New Zealand." The days of cock-fighting are over, but crimes are still committed in the name of "sport."

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*Being a commentary on chapter iv of *The Naturalization of Animals and Plants in New Zealand*, by the Hon. Geo. M. Thomson, M.L.C., F.L.S., &c.

†HARTERT, JOURDAIN, TICEHURST, and WITHERBY, *A Hand-list of British Birds*, 1912.

With regard to the Tasmanian swamp-quail (*Synoicus diemenensis*), a recent record confirms Mr. Thomson's supposition that this species is still present in the Auckland Province. Mr. J. Drummond, in his useful "Nature Notes" (*Auckland Weekly News*), records (1st June, 1922) what appears to be this species from Pukeraka, Bay of Islands. It may be distinguished from the commoner Australian swamp-quail (*S. australis* Tem.) by its larger and more handsome appearance, and by the larger eggs, which are yellowish-olive in colour, with more distinct markings.

The distribution of some of the species is well worth study. Even of the thoroughly established ones, some, like the house-sparrow, cling tenaciously to the settled areas, while others, like the chaffinch and blackbird, sometimes occur in the very "back of beyond." Contrary to one authority quoted, I have seen the song-thrush well above the bush-line on the Tararua Range, at an elevation of 4,000 ft.

On the west coast of the North Island—the scene of most of my observations—the hedge-sparrow is common in the Wellington district, but is totally unknown at Wanganui. At the latter place the Indian mina is extremely abundant, but does not occur south of Palmerston North. There is continual rivalry between the latter bird and the starling, which has apparently driven the mina completely from the Wellington district, where it was once plentiful. Palmerston North appears to be the "no man's land" where the issue is still in doubt, and where fights for nesting-sites have been observed. The starling is the dominant species, since it occurs abundantly even where the mina is also plentiful—namely, in the northern half of the North Island, where possibly the climate, more like that of its native home, may give the mina a better chance to resist the attacks of its rival. I have known a mina to swoop repeatedly at a person in the vicinity of its nest.

Mr. Thomson considers that the low nesting-sites of the hedge-sparrow render its increase liable to be limited by abundance of cats or stoats. I have, however, found the nest at least 15 ft. up in a *Pinus radiata*, and am of the opinion that the habit of the species has somewhat changed in this respect.

With regard to the linnet, Mr. Thomson writes: "The failure of this species to establish itself in New Zealand is one of the most inexplicable problems in animal naturalization. Some allied species have become very common, but the linnet disappeared soon after liberation." I cannot understand this statement, since on the west coast of the North Island, the only district on which I can speak with authority, the linnet is quite plentiful. Nor is this a recent increase, since Sir Walter Buller (*Supplement*, 1905), speaking of the Levin district, says, "Instead of the song of native birds, you have *on all hands* the familiar notes of the sparrow and the greenfinch, the *linnet* and the goldfinch." (The italics are mine.) I am well aware that the greenfinch is often called "green linnet"; but there should be no confusion possible between the birds in any of their seasonal phases of plumage, nor between the nests or eggs, all of which are abundantly distinct. The lesser redpoll, which is far less common than the linnet in the Wanganui district, is also easily distinguished, as are equally its nest and eggs. The latter are far smaller than those of any

other introduced bird, the only other eggs which approach them in smallness of size being those of the goldfinch, and these are of slenderer shape, with very little bluish tinge to the ground-colour. The redpoll's eggs are more rounded, like a miniature linnet's, but with a strongly bluish ground-colour, while that of the former is whitish. The linnet is mentioned as an established species in the *Hand-list* published by the Dominion Museum in 1909.

In conclusion, perhaps an ornithologist may be permitted a few general reflections on the whole question of bird acclimatization. In reading Mr. Thomson's account the most unprejudiced person cannot fail to be astonished not only at the injudicious and ill-advised choice of species to be introduced, but also at the casual nature of the records kept, the failure to ascertain whether attempts had previously been made to introduce a particular species, or to analyse the reasons of failure—in short, the lack not only of scientific consultation, but of the most elementary common-sense. The introduced small birds became a pest of no small magnitude—barn-owls were introduced to cope with them—and in the next report of the society we read, "They are now to be seen of an evening flying about the straw-stacks at West Taieri, and, *as they live almost entirely on rats and mice*, we feel sure the public will protect them." (The italics are Mr. Thomson's.)

It is significant that of all the species introduced only one has had no complaints made against it, and this, the hedge-sparrow, is one of the partial failures of acclimatization, since its spread has been extremely limited.* It is a matter for rejoicing, not only to the ornithologist but also to the farming community at large, that less than 20 per cent. of the species which wilful ignorance and unrestrained sentimentality let loose in this country survived to realize the hopes of the importers, and incidentally to prove, at the expense of the cultivator, the criminality of their achievement. May we hope that a strong body of public opinion will prevent such mistakes in the future!

DISEASES OF CAPTIVE FISHES.

The Gas-bubble Disease.

By MAXWELL W. YOUNG, F.C.S., Biologist, Portobello Marine Fish-hatchery and Biological Station, Dunedin.

SOME time ago a trumpeter (*Latris lineata* Forster) which had been in captivity for about eighteen months was found to have a transparent film growing over its right eye. The fish was kept under close observation, and

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*See, however, a Natural History Note in the last issue of this *Journal* (vol. 5, No. 6, p. 346), by Mr. H. Guthrie-Smith, recording its recent arrival in Hawke's Bay (1922). Mr. H. Drew has also observed the hedge-sparrow recently in Wanganui, where it was previously unknown.

it was noticed that although the eye could be quite clearly seen through the bubble which had formed, completely covering the eye, the fish was apparently blind on the affected side. This was confirmed at every feeding-time, as the fish would take only such food as came within the range of vision of the normal eye.

The appetite of the fish was impaired for several weeks, but it is now eating as voraciously as it did when in good health. The bubble has not diminished in size, and the fish is still blind. There is, however, no sign of the eye itself being affected, which is usually the case in the advanced stages of this disease.

There is only one other record of any fish suffering from this particular disease while in our aquarium, though in some of the American aquaria it is very prevalent. In the American cases it was found that the disease was fatal, all specimens that were not treated dying within a few weeks' time from the first appearance of the bubble. After exhaustive experiments Gorham* came to the conclusion that the trouble was caused by the reduction of pressure, due to the fish being transferred from deep water to shallow aquaria. It has been noticed that fish whose habitat is in shallow water are never affected by this disease. He found no signs of any micro-organisms that could produce the gas.

In our other recorded case, a sea-perch (*Scorpaena percoides* Richardson), the trouble was of a more serious type. On the 1st February, 1922, a film was noticed covering about one-quarter of the eye. The film in this case was of a dirty-yellow colour, as if there was a layer of matter behind it. A week later the film had covered the eye completely, but was not as distended as in the case of the trumpeter. The fish was kept in the glass aquaria until the 19th February, by which time the eye was apparently rotten. The perch refused all food after the first week of the disease, and ultimately succumbed six weeks after the first appearance of the film.

It has been recorded* that if fish suffering from gas-bubble disease are transferred, as soon as the first symptoms are noticed, to comparatively deep ponds (16 ft. or over) the eyes become normal in approximately twenty-four hours. Unfortunately, our deepest pond is barely 6 ft. deep, so I am unable to check this interesting statement.

When one comes to look for the cause of the disease it is to be noticed that the change in pressure that a fish living in 5 fathoms of water has to withstand when transferred to an aquarium containing only 2 ft. of water is considerable. In the first case the pressure is approximately 28 lb. to the square inch, which is quickly reduced to a trifle over 15 lb. to the square inch. In the case of fishes living in deep water the reduction of pressure and the subsequent expansion of the gases of the air-bladder and other parts of the body is so great that the fish are dead or dying when they reach the surface. *Post-mortem* examination shows the air-bladder to be ruptured, the contents of the stomach ejected, and the eyes protrude from their sockets.† If by any means the change of pressure could be spread over a period sufficiently long to allow the expanded gases to be absorbed by the walls of the air-bladder, or otherwise disposed of, slowly and without damage to the tissues, the disease would probably not occur.

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* F. P. GORHAM, The Gas-bubble Disease, *Bull. U.S. Fish Comm.*, vol. 19, pp. 33–37, with pls., 1899 (1901).

† P. REGNARD, *Compt. Ren.*, vol. 108, p. 745.

EXPERIMENTS IN THE RESISTANCE OF ARTISTS' WATER-COLOUR PIGMENTS TO THE EFFECT OF LIGHT IN NEW ZEALAND.

By M. CROMPTON SMITH, Chief Draughtsman, Lands and Survey Department, Wellington.

THE survey system of New Zealand inaugurated in 1876 required the use of colour upon the map records in order to distinguish between the numerous classes of information of technical and general import which required to be written upon them. As these data are of permanent value in connection with the land titles which are subsequently based upon them, it is important that the colours used for recording them shall be as permanent as can be secured. The colours are used in nearly all cases singly—*i.e.*, not mixed together to form other tints—so that chemical interaction plays a very slight, if any, part in causing them to fade or degrade. The chief factor in degrading them, when this occurs, is the action of light—the paper on which they are used being drawing-paper of the best quality and purity.

A considerable number of pigments, nearly all in the dry cake form, were taken and spread upon good drawing-paper, upon spaces 3 in. to 4 in. square, in a strong colour tone, about half-saturated. One-half the coloured spaces was covered from light by black paper reinforced by mounted drawing-paper, and in a picture-frame, under glass, but not sealed from air-changes, were exposed at a window for a six-months period. Upon the glass of the frame was also painted a strip in oil-colour, reinforcing again the covering over the hidden portion of the colours within. At the window the colours received the full blaze of sunlight for rather more than half the sunny hours of the day. The test is of a very searching character, for in the earlier experiments, when the covered portions had only one thickness of mounted drawing-paper over them, the coloured spaces were actually printed through the thick drawing-paper on to the strawboard backing, which was bleached by the sun's rays between and around the spaces.

The pigments were selected from among those of some seven makers—five English and two French. They did not by any means include all made by each, but chiefly those whose stronger colours and reputation for greater or less permanence seemed to recommend them for use. Such other qualities as body, covering-power, freedom of working, and drying-power, although affecting the final choice, are not among the recorded characteristics.

The trials naturally practically accorded in their results with well-known tests as recorded in existing text-books. It was chiefly as an object-lesson in confirmation of these, and as an investigation into the character of present-day manufactures, several of which are new and have no such recorded tests, that the experiments were undertaken.

An illustration of the bearing of these experiments is provided by Prussian green, a mixed pigment consisting of Prussian blue and gamboge: the latter, being non-permanent, faded out, leaving the blue. It was the

practice in offices to record the bearings of lines when upon the magnetic meridian in Prussian green, but when upon true meridian in Prussian blue (too close an approximation of colour, anyhow, for defects of colour-vision). The tests show that, in use, as time goes on and maps are exposed to light the green magnetic bearings automatically turn into true-blue bearings on the records by the fading of the gamboge constituent, apparently changing the direction of lines by some 15 degrees of arc, with disastrous possibilities to subsequent work based upon them. This, of course, is an extreme instance; but, like that of crimson lake and carmine—two much-used colours which fade completely out and disappear—it illustrates the need for attention to the quality of permanence under light-action.

In the following description the amount of fading or determination is an eye estimate only and is not measured. The following were the pigments tested, with the results (for obvious reasons the makers' names are not given) :—

Yellows.

Lemon cadmium	Unchanged.
Pale cadmium	,,
Lemon yellow (two samples)	,,
Azo yellow	,,
Cadmium yellow	,,
Aurora yellow	,,
Deep cadmium	,,
Indian yellow	,,
Aureolin (two samples)	,,
,, (third sample)	Faded and degraded (different make).
Gamboge	Much faded.
Gallstone	,,
Alizarin yellow	,,
Spectrum yellow	Unchanged.
Chrome yellow	Deepened and darkened.

Reds.

Rose madder	Good deal faded.
Pink madder	,,
Madder carmine	Unchanged.
,,	Slightly faded.
Carmine lake	Almost gone.
Crimson lake	Quite disappeared.
Alizarin scarlet	Unchanged.
Scarlet madder (alizarin)	Much faded.
,, (n.o.e.)	Faded.
Alizarin carmine	Slightly faded.
Alizarin crimson	Faded.
,,	Unchanged.
,,	Slightly faded.
,,	Faded.
Permanent crimson (alizarin)	Much faded.
Laque fine (alizarin ?)	,,
Rouge rubis (alizarin ?)	Quite changed colour.
Spectrum red (alizarin ?)	Much faded.
Cadmium red (eight samples)	All unchanged.

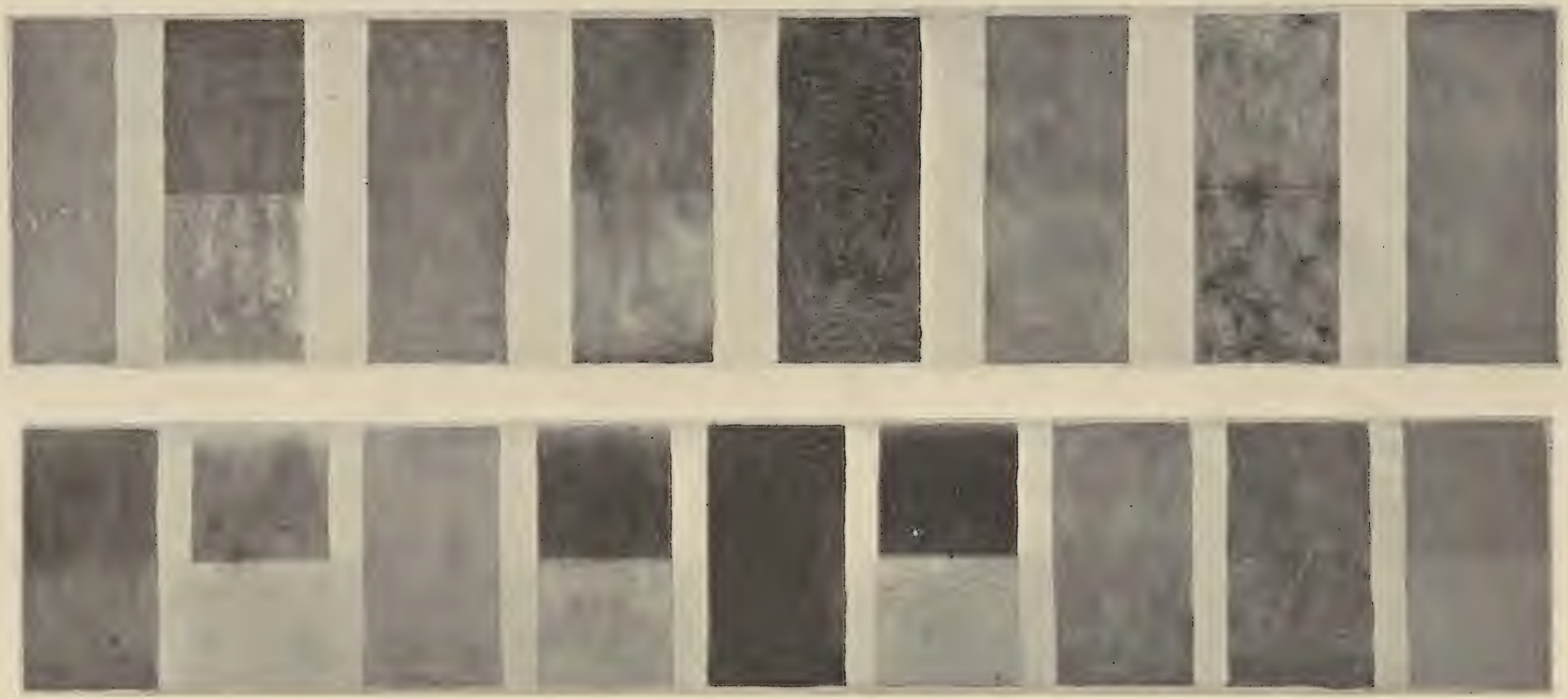


FIG. 1.—Chart indicating effect of light. Half of each colour was exposed, and the plate above shows the result of light action.

(Reproduced from panchromatic plate by Government Printing Office.)

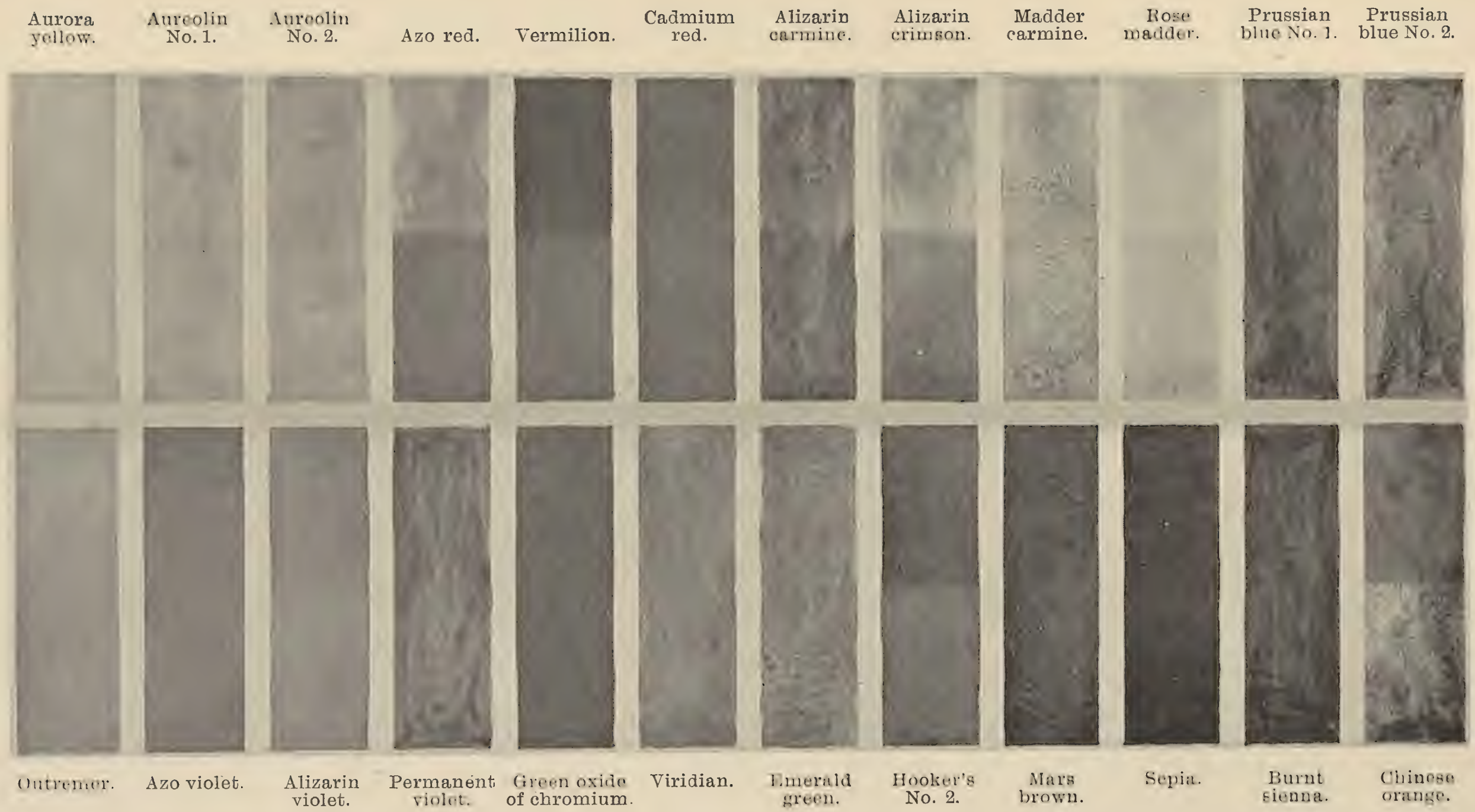


FIG. 2.—Chart indicating effect of light. Half of each colour was exposed, and the plate above shows the result of light action.

(Reproduced from panchromatic plate by Government Printing Office.)

Reds—continued.

Azo red	Much faded and disintegrated.
Vermilion (eight samples)	All turned brown.
Scarlet lake	Turned brown.

Blues.

Genuine ultramarine	Unchanged.
Sapphire blue	,,
Ultramarine ash (blue)	,,
Indigo	Much faded.
Prussian blue (four samples)	Unchanged.
Alizarin blue	,,
Cyanine or Leitch's blue (three samples)	,,
Cerulean blue (two samples)	,,
Outremer (French ultramarine)	,,
Cobalt (three samples)	,,
New blue	,,
Permanent blue	,,
Smalt	,,

Purples and Violets.

Purple lake	Almost disappeared.
Purple madder	Slightly faded.
Phoenician red	Good deal faded.
Azo violet	Little faded.
Spectrum violet	Faded.
Mars violet	Unchanged.
Alizarin violet	Faded and degraded.
Permanent violet	Unchanged.

Greens.

Prussian green	Changed to blue.
Cadmium green (two samples)	Unchanged.
Cobalt green	,,
Emerald green (three samples)	Disintegrated and faded.
Hooker's green	Changed to blue.
Green oxide of chromium	Unchanged.
Viridian	,,
Freehold green	,,
Chinese green	Very slight fading.
Alizarin green	Much changed.
Sunny green	Unchanged.

Orange.

Neutral orange	Unchanged.
Burnt sienna	,,
Chinese orange	Much faded and disintegrated.
Mars orange	Unchanged.

Browns.

Brown madder	Slightly faded.
Mars brown	Unchanged.
Sepia	,,

Browns—continued.

Page's sepia	Very slight fading.
Intense brown	Unchanged.
Turner brown	,,
Cologne earth	,,

Greys and Blacks.

Neutral tint	Much changed.
Charcoal grey	Unchanged.
Hill grey, cool	,,
,, warm	,,
Indian-ink wash	,,
Sky grey	Changed in colour.

White.

Chinese white	Unchanged.

From the point of view from which these trials were made—which is not that of the artist, but more nearly similar to that of the illuminator—the discoveries are as follows: The emphasis on the unreliability of vermilion, and the excellence of cadmium red, or scarlet, which closely resembles it in colour but is rather more brilliant and without its defects; the extent to which rose madder fades, and the permanence of its close ally, madder carmine; the permanence of the Indian yellow, contrary to its reputation (perhaps explained by its not being the genuine article, but a substituted manufacture), and the excellence of the new yellow (azo yellow) and the new green of cadmium. The pale cadmiums also have stood, although their permanence is considered doubtful by the authorities.

Several of the pigments, from their somewhat pasty nature, appear more suited to oil or opaque painting than pure water-colour, while several of the alizarin colours vary a good deal with different makers in the smoothness and ease of their washes as well as in the degree of fading.

It will be seen that a number of staunch old favourites among the earth colours have not been tested. Their durability is thoroughly well known; and in several instances their beauty does not lie in their brilliance and strong contrast, which is required for technical details.

The pigment named "freehold green" is a mixture of ultramarine ash and viridian, and is a permanent substitute for Prussian green, which it closely resembles in colour. The hill greys are simple mixtures of cobalt and light red, and are substituted for the work for which neutral tint was used, though not intended to be very close in colour.

Colours when used on maps are often brought in contact with the mountants which are used when paper or cloth is pasted down. This brings in an element of destruction at once, for the pastes often contain preservatives, sometimes formalin, which discharge some of the colours almost immediately. Cheap papers and cardboards also contain chemicals, such as hyposulphite of soda, used in the bleaching or other process of making, which are not washed out: these also are among the destructive forces to be guarded against. Pure unmounted paper and the best class of colour are alone to be relied on for permanence when the highest degree is sought.

THE FISHING INDUSTRY OF THE CHATHAM ISLANDS.

By MAXWELL W. YOUNG, F.C.S., Biologist, Portobello Marine Fish-hatchery and Biological Station, Dunedin.

A VISIT to the islands during 1922 was undertaken at the instigation of Mr. E. G. F. Zohrab, managing director of the Chatham Islands Fishing Company, Wellington. Mr. Zohrab kindly made me the offer of a free return passage to the islands by the company's steamer. This was granted with the primary object of enabling me to increase my knowledge of the life and habits of certain New Zealand fishes, particularly the blue cod (*Parapercis colias*). I was also to advise the company of any technical improvements that would place the works on a more efficient footing.

TRANSPORT.

Communication with New Zealand is maintained by an irregular steamer service. The s.s. "Rama" calls at the islands when the freezer is nearly full, so the time between visits depends entirely on the success of the fishing. At certain seasons boats are sent down to remove live-stock. Wireless communication is maintained at all times.

None of the roadsteads possesses a wharf that the steamer can berth at, and only at Waitangi is there a jetty for the convenience of the surf-boats. This is a very serious matter, as the steamer can only proceed with her work when the weather is fine. None of the anchorages is safe in all winds. As there are no roads in the accepted sense of the word, a steamer-wharf at either Waitangi or Owenga would hardly solve the problem, as the inhabitants of the rest of the island would have no means of getting their goods to their final destination. Roads could be made if the people were sufficiently energetic. The country is nearly all flat, so there are no engineering difficulties in the way.

To unload their fish from the motor-boats at Owenga the fishermen bag them, place them in dinghys, and row round a spit of land, beaching their boats on the foreshore below the freezer. An appreciable amount of fish is lost each year through the dinghys being swamped on the trip round to the beach.

Export Loading Arrangements.—The frozen fish are loaded into drays at the freezer, carted into the water as far as possible without getting the fish wet, loaded into surf-boats, and from them into the steamer. The Fishing Company offered to pay the fishermen a fair wage to build a stone jetty during the off fishing season; but after the work was well under way the men refused to continue unless they were paid a considerably higher rate than the company was prepared to concede, so the work had to be stopped. This appears to have been very foolish of the men, as there is little work for them to do at that time of year, and they would save a lot of time and money when landing their fresh fish at such a jetty.

The facilities for inland transport on the island are very meagre. There is not one road that is anything more than a bridle-track. Even between Waitangi and Owenga the road is so ill-defined that a stranger can quite easily get off the track in fine weather. When the weather is bad the

bogs and watercourses make the road difficult even to experienced horsemen, and it would then be foolhardy for a stranger to undertake the trip alone.

FREEZING-WORKS AT OWENGA.

Power is supplied by a steam-engine assisted by a suction-gas plant. The freezing machinery consists of two Hercules dry-compression machines. These are capable of dealing comfortably with 5 tons of green fish daily, and up to 9 tons if pushed hard; but, of course, it requires time to get the chambers down to zero again after a heavy overload. The usual pumps get their water from a passing creek, which, lower down, takes the drainage from the works.

Light is supplied by means of a small dynamo driven from a fly-wheel on the shaft of the main power-engine.

There are four freezing-chambers—two large and two small. The cleaning-room is much too small, and is somewhat badly arranged. The flooring is not sufficiently sloped to carry off the surplus water quickly. The cleaners are paid £2 6s. 8d. per ton for blue cod, and special rates for groper and other fish.

The cleaners remove the offal in baskets to the loading-platform. It is then transferred to drays, and allowed to stand all night. In the morning, when tide and weather permit, it is carted out to sea and dumped. This is a waste of a valuable by-product, and I will deal further with it in my concluding remarks.

Ten boats are employed, each carrying a crew of from two to three men. These are a fine lot of boats, rather heavily engined for their size, but very seaworthy. The men are paid on the basis of their catch, at the following rates:—

Blue cod: Flat rate, 1d. per pound for the uncleaned fish. If the boat has over 3 tons for the month (a low catch), 1¼d. per pound. If the boat catches her tonnage (16–24 tons) per annum, the men are paid at the rate of 1½d. per pound. Most of the boats, if fished regularly, manage to get their tonnage without much trouble.

Groper: At the rate of ¾d. per pound.

Trumpeter: At the rate of 1d. per pound.

REPORT ON THE FISHING-CAMP AT OWENGA.

The conditions at this camp are not what they should be, and are far from what they could be made if more land in the immediate vicinity of the boat-harbour were available. The owners of the Owenga Estate, I understand, are not prepared to sell any of their land on the foreshore, the consequence being that the fishermen have had to build their huts on a block of 20 acres of bare grazing-land belonging to the Fishing Company, and required by them for the grazing of horses necessary in connection with their business. There being no certainty of tenure to the fishermen, they naturally have no incentive to make improvements of any kind, with the result that their huts are more or less huddled together, and there is an utter lack of any privacy whatever. As a number of the fishermen are married men with children, these conditions call aloud for improvement.

I am informed that the company has from time to time approached the neighbouring owners of the Owenga Estate with a view to purchasing some of the foreshore adjoining the freezing-works, in order to settle the fishermen under better conditions, but so far has been unsuccessful in its

negotiations. This matter is the most important that I have to deal with, as until we get better living-conditions we cannot hope to get the better class of fishermen to stay.

From time to time the local Inspector of Fisheries has pointed out the condition of the camp in the Marine Department's annual reports. The company want each family to have a good house, and sufficient land for a garden and grazing for a horse and cow.

Approximate Distances from Owenga to Fishing-grounds. — Star Keys, thirty miles; Forty-fours, thirty-five miles; Hamilton Reef, forty miles; South-east Island, forty miles; Okawa, twenty-two miles. The boats also fish in Hansen Bay in bad weather, two to four miles from home.

The fish make for certain grounds at certain seasons, travelling south—roughly, as follows: April–May, Okawa, Hansen Bay, and Manakau; June–July, Forty-fours, Tupuangi, and Manakau; August–September, Star Keys, Donaldson Reef, South-east Island; October–November, Eastern Reef, Hamilton Reef, South-east Island.

The fish are sometimes seen travelling in great quantities near the surface. I saw this personally myself on a trip to Star Keys.

Benzine is supplied by the company at pre-war rates—£1 5s. per case—and lubricating-oil and launch stores at reasonable rates.

General Remarks.

In conclusion, I wish to make a few remarks on various pertinent matters, and venture to put forward some suggestions.

Stencilling. — The cases are at present branded "New Zealand Blue Cod" on one side and "C.I.F. Co." on one end. I think it would be as well if "Chatham Island Products" was also on the case, to differentiate between these fish and the New Zealand ones, as the island fish are undoubtedly of a superior class.

Works.—As far as the works are concerned, there is little to be said. Personally I think that the steam-engine, with suitable gearing, could drive both the compressors, in which case one could dispense with the suction-gas plant and convert the gas-engine into a stand-by oil-engine. This would lessen the cost of keeping the works in order, as it is very evident that the fumes from the gas-producer have a corrosive action on the iron of which the works are built. A small benzine-engine of, say, 1 horse-power to drive the dynamo would be very useful; as things are at present, when the steam-engine is not in use or broken down the works have to be illuminated by means of oil-lamps.

Cleaning-shed.—This should be entirely remodelled, as the present one is out of date. A greater slope should be given to the floor, so as to allow the waste water to get away more freely than it does at present. The bin for receiving the fish should be half as large again, and made of reinforced concrete, with drainage-holes at the bottom. The room should be made a good deal larger, and special attention paid to the fact that there should be no corners in which dirt may accumulate. At present the bearers project into the room, and thus with the corners made by the lining are very hard to keep clean. The company has this matter under consideration, and if lamb-freezing is undertaken additions and alterations will have to be made to the present building.

Cleaning. — More care will have to be shown in this department if the company is to keep up to its present high standard, as the men

are inclined to hurry too much over their work unless the manager is personally overseeing operations.

Offal.—The whole of the area in front of the offal-loading platform—that is, from the creek to the box-shed and out into the main road—should be concreted, with sufficient slope for drainage into the neighbouring creek. At present the juices from the offal in the carts drain off overnight and fall to the ground, which, I need hardly point out, is not only insanitary, but costs money in disinfectants to keep the smell down in the warm weather. I have been informed since my return that the work will probably be put in hand this coming summer (1922–23) during the off fishing season.

If ever the works are remodelled the substitution of brine freezing for the present process should be seriously considered, as it is not only effective, but cheap to run, and has many technical advantages.

Camp.—I would recommend that, failing all negotiations, the necessary land should be taken under the Act to enable the company to proceed with their improvements. I am afraid that the Health Inspector would have some rather drastic measures taken if he inspected the present condition of things.

From information received since my return to New Zealand I learn that the company has made a start at digesting the offal, and both oil and manure are to be brought up by the steamer next trip to test the market values.

Establishment of a Combined Marine Biological and Meteorological Station.—It would be of great value to the industry and to science generally if we could establish the above station, and I see no reason why it should not be done. The appointee should undertake the following duties: (1) Meteorologist; (2) Marine Biologist; (3) Inspector of Fisheries.

Under class (1) he would have to make daily records of rainfall, wind, sun, barometer, thermometer (maximum and minimum). These would be of value to the fishermen in forecasting the weather, and on being transmitted to the Dominion Meteorologist daily by wireless would be useful to him and to mariners generally.

Under class (2) he should be prepared to collect specimens of the marine life, study the migration of fish and their foods, and generally collect useful scientific data.

Under class (3) he would have to carry out the usual duties of the inspectors, and give advice on fishery problems.

If the suggestion is approved, I would recommend that a married man not over thirty be appointed to the post—one able to ride, and prepared to stay at the islands for two years at a time, with three months' leave after that. A salary of £300 would, I think, be necessary to secure a suitable man.

Trawling.—With regard to this, I think that a start should be made, as I am of the opinion that there are good grounds to be found, and they would be well worth exploiting; but a charting and surveying expedition would be an advisable preliminary.

Crayfish.—At the present time these are not worth troubling about; but if trawling is ever started at the Chathams they would be well worth canning, as they are present in great numbers.

Bait.—I would recommend that some of the fishermen give the patent combined artificial baits and hooks, known as "strikers," a trial, as a lot of valuable fish is used annually for bait. I think they would be very suitable for blue-cod fishing.

THE POLYNESIAN STEAM-OVEN.

By ELSDON BEST, Dominion Museum, Wellington.

With illustrations by J. McDONALD.

THE steam pit or oven of the Maori is the universal mode of cooking throughout Polynesia. It has also been employed by races of many far-spread regions in olden times. At one period it was much used in the British Isles, and we have some account of it in the pages of Ossian, in the Battle scene.

There are many different Maori names for this steaming-pit; the two best-known names are *hangi* and *umu*. The process is essentially one of steaming, and cannot be termed baking. The illustration (fig. 1) shows an early stage in the process of *tao kai*, or food-steaming. In the excavated pit the fuel has been arranged and the cooking-stones piled on it. As the fuel is consumed by the fire the stones will sink into the pit. When the fuel has disappeared, save embers, the stones will have become exceedingly hot. The next act is to scrape out such embers, and leave naught save the hot stones in the pit. From this juncture there are two methods of procedure: in one all the hot stones are left in the bottom of the pit; in the other a number of them are taken out and arranged on the top of the foods to be cooked when they are placed in the pit. The former method is employed in cases where easily cooked articles or a small quantity is to be dealt with. The latter mode obtains when a larger quantity is to be served, or articles are included that need more cooking, such as a joint of meat.

With a stick used as a poker (*rorerore*, *kapekape*) the hot stones in the bottom of the pit are manipulated so as to present a fair surface on which to operate. A quantity of green leaves, branchlets, or fern-fronds is laid on the stones, and arranged as a bed on which to deposit the articles to be cooked. Thus a quantity of potatoes might be so deposited, with other vegetables on the top, and fish or birds placed on that. The food being all in order, it is then covered over with another layer of green leaves, &c. The water is then applied, splashed over the filled pit according to the judgment of the cook (fig. 2). This water percolates through to the hot stones and produces the steam that is the true cooking agent. Over the covering of green leaves, &c., flax mats are laid in several layers, and the whole then covered with loose earth, often padded down by the use of a wooden spade (fig. 3). In late times European spades or shovels have been used, and the coverings are often European sacks. We have seen old horseshoes used instead of stones for generating steam in the *umu*.

In many cases a woven band of long leaves, as those of *Astelia*, &c., was employed wherewith to line the sides of the pit, and this is termed a *koronae*, *kopaepae*, and *kororipo*. Leaves, &c., used as covering and as a bed for the food are *rautao*, *retao*, *ritaka*, and *tapaki*. The covering-mats are also called *tapaki*, and apparently *tapora* in some districts.

One name for these food-steaming pits is *kopa*, a much ill-used term, for it has been corrupted into "copper" by the intrusive *pakeha*, who discourses of "copper mouree" with glib assurance.

FIG. 1.—Stones in position and in process of heating.

FIG. 2.—Splashing water over the oven.

FIG. 3.—Covering the oven with mats.

FIG. 4.—Uncovering the cooked food.

The *umu konao* is a form highly appreciated by the Maori—indeed, it is a different process, for in this method no fire is kindled in the pit. The stones are heated in a fire apart from the *umu*, and, when sufficiently hot, are transferred to the pit. Natives maintain that this is a far superior style of cooking to the other. Whanganui natives seem to apply the term *kohua* to this form of steam-oven, but it is, in some places, used to denote stone boiling.

An implement called a *paretai* was sometimes used among the Ngati-Porou folk in manipulating the *hangi*, as in cleaning out the pit and covering with earth. Mr. White mentions a wooden tool called *uru*, apparently a form of spade, used for a similar purpose.

Care had to be displayed in selecting stones for cooking purposes. Many kinds would not stand the fire, but were shattered by the heat. Good cooking-stones were highly prized. In some cases, when suitable stones were unprocurable, indurated clay or pumice has been used for oven-heating purposes. The uncovering of an *umu* is done carefully, lest some earth be spilled among the cooked food (fig. 4).

The Whanganui natives occasionally employed, in former times, a singular mode of cooking birds that was termed *turchu;* it seems to have consisted of burying the birds in wet earth and then making a fire over them. The words *kohu*, *tukohu*, and *kohupara* define a secondary method of cooking, in which the food was placed in a vessel which was put in the pit and covered up.

THE NEOLITHIC MAORI.

By ELSDON BEST, Dominion Museum, Wellington.

Illustration by J. MCDONALD.

IN the task of grinding his stone tools the Maori possessed no rotatory grinding-stone to accelerate the process. He simply rubbed the tool on a slab of sandstone. So accustomed was he to this mode of grinding that I have known natives who were engaged in bush work to ignore the European grindstone provided for their use, and sharpen their steel axes on the *hoanga* of their ancestors.

In using his *hoanga*, or grinding-stone, the Maori preferred to immerse the lower part of it in water, as shown in the illustration. This saved him the trouble of frequently pouring water on the stone. Pieces of sandstone of a suitable kind, both coarse and fine grit, were prized in former times, and such material was often procured from a considerable distance. Certain places were famed for the quality of sandstone procurable thereat; such a place is Oruhi, at the mouth of the Whareama River.

The task of grinding a stone adze, termed *orooro toki*, called for the same rubbing process as was employed in imparting a smooth and sightly surface to any stone artifact. Always the implement was rubbed on the grinding-stone, though in the manufacture of certain objects both stone

rasps and gravers were employed. All kinds of sandstone are personified in one Hine-tu-a-hoanga, the Grindstone Maid, but each kind has its own specific name, as *matanui*, *matarehu*, *tunaeke*, *totara*, *wawatai*, *kauheke*, *papanui*, and the *pipiwai* or *reke-pounamu*. In native myth Hine the

Grinding a stone adze by rubbing it on a *hoanga*, or slab of sandstone.

Sandstone Maid is the child of Tuamatua, the origin and personification of all stone, who was the offspring of Tane and Hine-maunga, the Mountain Maid.

The Maori employed certain charms when grinding a stone adze, and such formulæ were believed to greatly assist the process. Rata, the son of the Sandstone Maid, was closely connected with the art of grinding, and the word *rata*, in vernacular speech, means "sharp."

The illustration shows Apirana Tukairangi sharpening a stone adze at the Operiki Creek, Whanganui River.

LEPIDOPTERA FROM HAWKE'S BAY.

By AMY CASTLE, Entomological Division, Dominion Museum.

THE early part of the 1922–23 season proved much more favourable for insects in Hawke's Bay than the previous season, and the Dominion Museum received nearly a thousand specimens collected at the Pukeora Sanatorium, Waipukurau, by the Director of the Museum, Dr. J. Allan Thomson. The brilliant blaze of electric lights is visible for many miles on the Ruataniwha Plains, and the open shelters readily admit all insects attracted by the light. Two-thirds of the specimens collected were Lepidoptera-Heterocera, the remainder being Neuroptera, Diptera, and Hymenoptera. No recorded collections have been made from this locality previously, and the present collection, though containing no new species, includes several rarities and adds considerably to our knowledge of the geographical distribution of these species. The following ten species are, I think, worthy of record :—

Physetica coerulea has hitherto been recorded from Waipori, Macetown, Vanguard Peak, Mataura, Orepuki, Wakatipu, Alexandra, Christchurch, Rakaia, and Blenheim. The Dominion Museum has one specimen from Moumahaki and several from Titahi Bay. It is apparently a much rarer insect in the North Island.

Dipaustica epiastra (one specimen).—Recorded from Makara, Wellington. In 1919 Mr. C. Clarke, of Dunedin, captured two specimens, at Waimarino and Rangataua respectively.

Melanchra coeleno (one specimen).—Recorded from Invercargill, Queenstown, Tomahawk, Dunedin, and Waikouaiti. One specimen in the Dominion Museum collection, from Titahi Bay.

Melanchra mollis (one specimen).—Recorded from Invercargill, Wallacetown, and Dunedin. Eleven specimens from Titahi Bay, captured by Mr. C. O'Connor (1910), in the Dominion Museum collection.

Phrissogonus laticostatus (three specimens).—Recorded from Nelson, Otaki, Wanganui, Auckland, and the Kermadec Islands. One specimen, from Marton, in the Dominion Museum collection. An Australian immigrant.

Chloroclystis dryas (twelve specimens).—Recorded from Wellington. One specimen, from Mount Hector (3,000 ft.), in the Dominion Museum collection.

Chloroclystis maculata (one specimen).—Recorded from Bluff, Queenstown, Otira River. Three specimens from Lyttelton and two specimens from Titahi Bay in the Dominion Museum collection.

Hibernia indocilis (ten specimens, males).—Recorded from Queenstown and Christchurch. One specimen (male) from The Peak, Lake Coleridge (2,500–4,000 ft.). Three specimens (males), from Awapiri, collected by Dr. J. Allan Thomson, 1919, in the Dominion Museum collection. The female of this moth is semiapterous, and rare in New Zealand collections.

Crambus angustipennis (one specimen).—Recorded from Invercargill, Christchurch, Rakaia, Castle Hill (2,500 ft.). Rare in South Island.

Platyptilia heliastes (one specimen).—Recorded from Lake Wakatipu, Castle Hill and Mount Arthur.

Appended is a list of the Heterocera collected at Waipukurau :—

Heliothis armigera.
Euxoa admirationis.
Agrotis ypsilon.
Aletia unipuncta.
Aletia sminthistis.
Dipaustica epiastra.
Physetica caerulea.
Persectania disjungens.
Melanchra insignis.
—— *coeleno.*
—— *omoplaca.*
—— *mollis.*
Ariathisa comma.
Cosmodes elegans.
Elvia glaucata.
Phrissogonus laticostatus.
—— *denotatus*
Chloroclystis dryas.
—— *maculata.*
Hydriomena deltoidata.
—— *similata.*
—— *subocharia.*
Asthena purpureata.
—— *pulchraria.*
Venusia verriculata.
Asaphodes megaspilata.
Xanthorhoe rosearia.
—— *venipunctata.*
—— *cinerearia.*
—— *rubropunctaria.*
—— *beata.*
—— *aegrota.*
Epirranthis hemipteraria.
Leptomeris rubraria.
Hibernia indocilis.
Declana junctilinia.
—— *atronivea.*
Hepialus virescens.
Porina despecta.
—— *umbraculata.*
—— *signata.*
—— *cervinata.*
Tortrix postvittana.
—— *excessana.*
Cnephasia jactatana.
Crocydopora cinigerella.
Crambus angustipennis.
—— *flexuosellus.*
—— *vitellus.*
Diptychophora pyrsophanes.
Gadira acerella.
Nymphula nitens.
Diasemia grammalis.
Mecyna flavidalis.
Scoparia philerga.
—— *leptalea.*
—— *rotuella.*
—— *aspidota.*
—— *cataxesta.*
—— *petrina.*
—— *submarginalis.*
—— *indistinctalis.*
—— *sabulosella.*
Platyptilia falcatalis.
—— *heliastes.*
Alucita innotatalis.
Borkhausenia ?
Izatha picarella.
Monopis ethella.

THE INTERNAL MITE OF THE DOMESTIC FOWL.

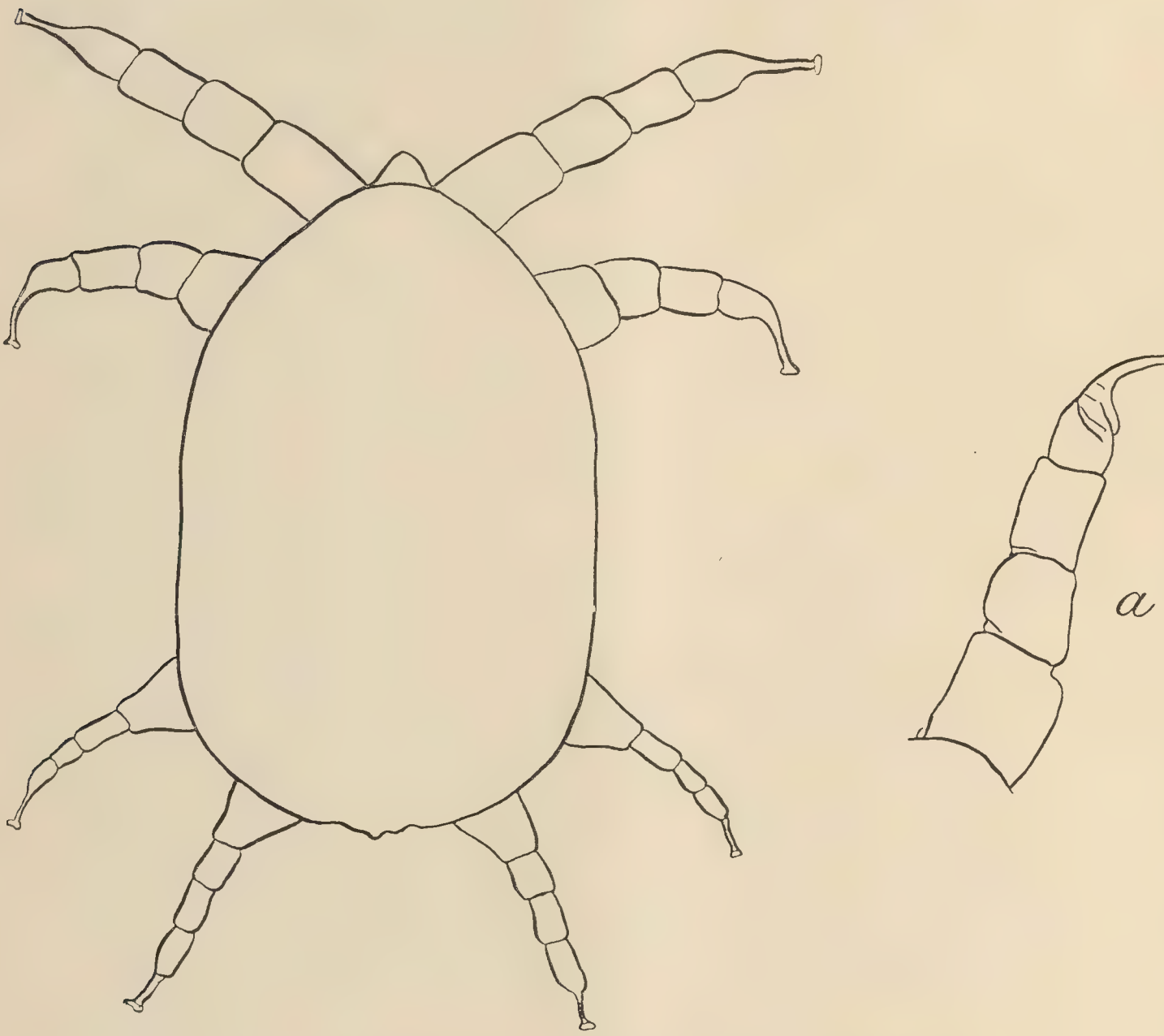
Its Occurrence in New Zealand.

By J. G. MYERS, F.E.S., Biological Laboratory, Department of Agriculture.

IN August, 1920, in the Wanganui district, a Black Orpington hen was dissected by the writer for the purpose of ascertaining, if possible, the cause of its death. The viscera, with the exception of the liver, appeared normal; but the latter was much swollen and discoloured, possibly owing to infection with *Coccidia meleagris*. Throughout the air-sacs, the body-cavity generally, and among and on the surface of the hepatic lobes were

thousands of small white mites, which have since been identified as the internal or pulmonary mite of the fowl (*Cytoleichus nudus* Viz.).

This mite is placed in a small family distantly related to the itch-mites, causing scabies in man and "scab" in sheep. One other member of the family is found sometimes on the skin of the fowl and at other times in a subdermal position, where it produces a limy cyst. This latter species is uncommon. A third kind infests the lungs of the prairie-dog in North America. With regard to *C. nudus*, the species under discussion, there has been some controversy as to its pathological importance. The English and American authorities, while admitting that large numbers



Cytoleichus nudus (Viz.). × about 100. *a*, second leg.

in the air passages and sacs may produce suffocation, are of the opinion that small numbers may be found in perfectly healthy fowls. Continental authorities charge it with causing enteritis and peritonitis; while Wildman, in 1915, said it "occupies the air-spaces and bronchi, causing a fatal disease." The latter author mentions the fact that a few cases have been recorded in human beings, but these were not in the lungs. The mite occurs in various birds of the fowl family, and sometimes in finches, throughout Europe and North America, and may easily have been overlooked in other places unless present in overwhelming numbers.

The individual mite is very small (about $\frac{1}{2}$ millimetre) and semi-globular in shape, with four pairs of fairly stout legs, of which the two anterior are considerably the larger. Every leg ends in a long sucker, by means of which

the mite is able to penetrate the tissues of the host. The shining body, with remarkably few hairs, is white or semi-transparent.

Observations elsewhere show that this mite brings forth living young which possess only three pairs of legs, instead of the four of the parent.

Up to the present this is the only recorded case known to me in New Zealand. The name has already been mentioned in *The Naturalization of Animals and Plants in New Zealand*, by G. M. Thomson, page 347.

NATURAL-HISTORY NOTES.

Notice to Entomologists.

The attention of entomologists throughout the world is called to the fact that, beginning with the volume for 1922, the preparation of the "Insecta" part of the *Zoological Record* is being undertaken by the Imperial Bureau of Entomology. In order that the *Record* may be as complete as it is possible to make it, all authors of entomological papers, especially of systematic ones, are requested to send separata of their papers to the Bureau. These are particularly desired in cases where the original journal is one that is not primarily devoted to entomology. All separata should be addressed to—The Assistant Director, Imperial Bureau of Entomology, 41 Queen's Gate, London S.W.7, England.

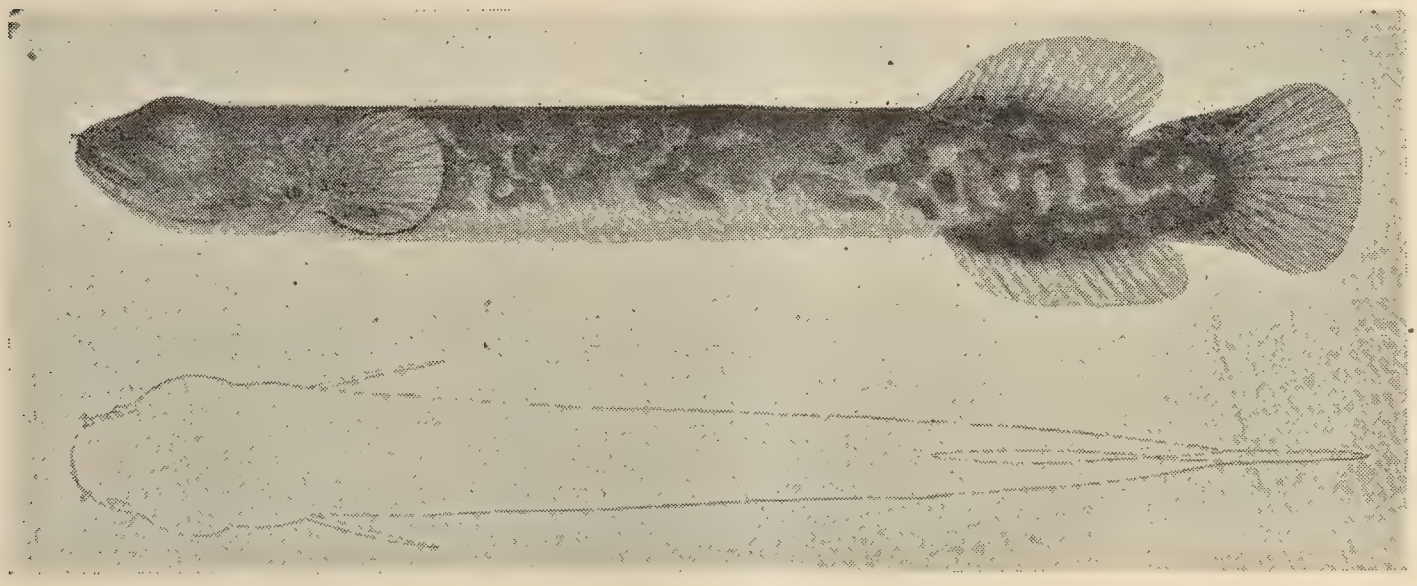
Feeding-habits of the Shining Cuckoo, by W. W. Smith.

The March number of this *Journal* for 1922, page 58, contains a short article by Mr. R. E. Grimmett entitled "Note on the Feeding-habits of the Shining Cuckoo." In the months of February and March, when the calls of the birds cease for the season, a number of them are seen daily feeding, in the manner described by Mr. Grimmett, on the hairy larvae of the magpie-moth (*Deilemera annulata* Boisduval). When observing the cuckoos lately with a pair of prism field-glasses, capturing and consuming the larvae, I noticed minute particles and a larger piece of something drop from the limb of the karaka-tree on which the cuckoo under observation was feeding. There were five cuckoos feeding on the larvae within a space of 2 chains. I changed my position as the birds moved, in order to observe them closely. I particularly noted that the birds when they descended into the masses of the introduced "Cape ivy" (*Senecio mikanioides* Otto ex Wulp.) remained some minutes in, or on, the vegetation, capturing the larvae. When they rose and settled on a tree-limb to consume them the birds were also a considerable time doing so. On crossing the stream and searching on the walk and vegetation under the trees on which the cuckoos fed I found a number of fresh skins of these hairy larvae. Some were torn; others were almost intact. I also found several agglomerated pellets composed of the compressed or empty skins of these hairy-coated larvae. The pellets when fresh are moist, and are coated with a saliva-like substance. At a distance of 12 to 15 yards I observed the actions of the cuckoos feeding very clearly. I found the fresh skins and pellets directly under the tree-limb where one of the birds

fed. Two of the birds that I watched were adults; three were young, in distinctly immature plumage. The cuckoos unquestionably collect a number of the larvae in the mouth before perching on some limb, where they continue to munch them until the viscera and intestinal matter is compressed from them, when they eject the skins. They certainly do not swallow all the larvae. I occasionally saw them wiping their beaks on the limb where they sit after munching the larvae. For the first time in my long experience with the larvae of the magpie-moth I have detected it attacking the leaves of sunflower-plants in two gardens in New Plymouth during this season. Hitherto I have known it to attack only species of *Senecio* and *Olearia*. It is also very destructive to cinerarias. It occasionally devours the fleshy upper and under surface of the more coriaceous leaves of some species, leaving the parenchyma uninjured. It is annually enormously abundant on the vast masses of the "Cape ivy" festooning the trees and trailing over the lower vegetation in the beautiful Huatoki Valley, in the town of New Plymouth.

Note on the Occurrence of the New Zealand Mudfish, or Hauhau (*Neochanna apoda*), by W. J. Phillipps, F.L.S., F.R.G.S., Dominion Museum.

Through the courtesy of Mr. W. B. Braddon, of Hokitika, two specimens of the mudfish, *Neochanna apoda*, have recently been received by the Dominion Museum. They were secured with considerable difficulty from a bush swamp some twelve miles inland from Hokitika. Mr. Braddon, who has had a wide and lengthly experience of West Coast conditions, informed



Mudfish (*Neochanna apoda*).

me that this species was now rare, and during the last twenty years had been found only on several occasions under white-pine stumps standing on low-lying heavy blue-clay country subject to flood. It is a peculiar fact that this fish is known so far only from two localities remote from each other, one being the small swamp area in the neighbourhood of Hokitika, and the other Rangitikei, in the North Island.

The example figured is taken from the unpublished drawings of the late F. E. Clarke which have been recently acquired by the Dominion Museum. The total length is 20·4 cm., and the accompanying formula reads as follows: D, 17; P, 13; A, 16; C, 16; H: B and T, 3 : : 17; B, 7. One of our recent specimens differs in having one ray less in the

dorsal fin. Examples to hand have total lengths of 10·4 cm. and 9·6 cm. respectively, and are evidently half-grown.

In a work which is now rare, Reid* made the following mention of this fish: "A peculiar fish which has attracted attention is the West Coast mudfish, a fish which was once supposed to take to and reside in the mud from choice. It has often been excavated from considerable depths in the clayey soil. As the waters dry up it is forced to wriggle into the mud at the bottom and sides of the swampy pools it inhabits. In some instances it has been known to follow down the moisture in holes left by decaying roots and get a considerable depth underground. When the surface of the ground has been perfectly dry, and the whole cleared and improved, the discovery of a healthy fish five or six feet under solid dry ground has been looked upon as truly miraculous. Its usual habitat is a pool or small creek on swampy ground, where it remains swimming freely nearly all the year round, the fry hatching in September or October, and young fish half an inch in length can be obtained in January."

During recent years nothing has been heard of this most interesting fish. As most people connected with fishery matters had never heard of a mudfish, inquiries which I was enabled to make at Hokitika in 1920 led me to the conclusion that the species had almost disappeared. It is to be regretted that at the present time no practical suggestion can be put forward for its protection and preservation. As the forest is gradually being cleared and the swamps drained, there is little doubt but that yet another animal unique in the natural-history world of New Zealand will become extinct.

REVIEWS AND ABSTRACTS.

The Venus-Sun Effect in the Horizontal Magnetic Field at Christchurch: Extract from the annual report of the Director of the Magnetic Observatory, Christchurch (H. F. Skey, B.Sc.).

In the annual report for 1919–20 there were published two diagrams showing the averaged annual march of horizontal force at Christchurch during the four years 1902 to 1905, and during the eight years 1913 to 1920. It should be remarked that the averaged march for 1913 to 1920 differs only very slightly from the averaged march for 1917 to 1920, showing that there is a close correspondence between the averaged march for the two consecutive sets of four years—1913 to 1916, and 1917 to 1920. It is well known that a marked eight-yearly periodicity exists between the heliocentric longitudes of the Earth and Venus, and a close four-yearly periodicity between the longitudes of the Earth and of Venus or anti-Venus. This almost proves that the magnetic changes on the Earth are chiefly due to some tidal effect upon the Sun, or matter connected therewith, due to the gravitational effect of the Earth and Venus.

Dr. L. A. Bauer states that in the course of time (say, seventy years) the mean annual variation of terrestial magnetism (from 140 years'

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* R. C. REID, *Rambles on the Golden Coast of the South Island of New Zealand*, p. 176, 1886.

observation in the Northern Hemisphere) changes its phase-angle at the commencement of the year by 180°. This seems to me to point to the planetary forces upon the Sun being able to completely reverse on the Sun either some static condition (such as shape) or the phase at January 0d. of some persistent natural oscillation in the Sun, which oscillation is the means by which the solar effect is sent out into the system. The solar corona seems to indicate the possibility of the Sun being surrounded by an electric field of force. Any change of shape would result in electrical surgings (in any changed condenser), and in the radiation of characteristic electro-magnetic waves more or less plane polarized into surrounding space. It is conceivable that these might have a characteristic effect upon any magnetized "receiver" in their path. Any theory involving the passage of electrons from Sun to Earth involves the certainty of slowly increasing the mass of the Earth, which is admittedly slowly increasing by the addition of meteoric masses. In the case of the Sun the effects might balance, but the Earth must grow from both causes. There is no doubt that the amount of energy which runs down into heat in the Earth in the course of such a magnetic storm as that of May, 1921, is very large, and it seems to me rather doubtful if it could be conveyed to the Earth by electronic streams from the Sun unless the streams were either non-divergent or specially directed by the gravitational field between Earth and Sun. Anyway, the recognition of a distinct "Earth and Venus relative to Sun" effect in terrestrial magnetism is of great importance, and I think that the Venus effect should be calculable, and so amenable to further investigation.

A regular beat in the solar system, such as that produced by the action of the Earth and Venus, must be in effect balanced by an inverse beat elsewhere in the system—that is, in the perturbations of the other planets and the Sun; also, the action of these two inverse beats must be accompanied by simultaneous beats in the ether or the medium conveying the gravitational force. If changes could be actually observed in the Sun or its radiation corresponding to these beats, then mankind would not be so tempted to suspect or to seek for a direct connection between gravitational energy and magnetic energy in the great laboratory of Nature. Such changes will certainly have to be looked for, and their existence proved or disproved, before we are satisfied, because we are unable in our laboratories to reproduce the conditions existing in the neighbourhood of the Sun—a region traversed radially by intense light-radiation, a gravitational field varying with immense rapidity radially, and the ether of which is continuously gaining or losing immense motions in the process of the conversion of potential to kinetic energy, or *vice versa*. Lord Kelvin has shown the well-nigh impossibility of our visible Sun being a strong-enough magnet to affect the Earth directly, but it is by no means certain that this applies to the conditions of the ether in the space surrounding the Sun. We have no experience of possible invisible non-material magnets, like we have of transparent matter. It would perhaps be easy to show that the local magnetic effects here are just now correlated with the occurrence of tides on the Sun itself; but correlation does not show necessarily a direct cause and effect, because two effects of the same cause are perfectly correlated with each other, and this applies to Sun-spottedness and terrestrial magnetism. But the establishment of correlation is always a step in the right direction, and sooner or later leads to the truth of the cause and effect.

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THE PRESENT POSITION OF THE ENDEMIC BIRDS OF NEW ZEALAND.*

By J. G. MYERS, B.Sc., F.E.S., R.A.O.U., Biology Division, Department of Agriculture.

INTRODUCTION.

THE birds of New Zealand are noted for two things—their uniqueness and their rapid disappearance. The ornithological heritage of the present New Zealand generation is a dissipated remnant of the most interesting avifauna on earth, wasted largely by the folly and negligence of those whose first care should have been its preservation for posterity. For the last forty years the history of the birds of New Zealand has been a record of disappearance and extermination. Even as long ago as 1896 Newton wrote, "In respect of extermination leading immediately to extinction, the present condition of the New Zealand fauna is one that must grieve to the utmost every ornithologist who cares for more than the stuffed skin of a bird on a shelf"; and, further, "the destruction of the original avifauna of this important colony, so thriving and so intellectual, is being attended by circumstances of extraordinary atrocity." It is not necessary here to enlarge on the details of the deliberate introduction of rabbits, followed by that of stoats, ferrets, and weasels; of the wilful importation of multifarious small birds and then of rapacious species—all expressions of criminal folly consistent only in their evil influence on the indigenous birds. The decrease of the native species, owing partly to the above causes, partly to the clearing of the forest, and partly to agencies unknown, for a time proceeded at such a pace that it became a habit to assume the inevitable doom of the majority of the indigenous land-birds. The main purpose of the present paper is to show that the position now is by no

* Read before the Australasian Association for the Advancement of Science, Wellington, January, 1923.

means so bad as even the most authoritative prophecies predicted. Inferences regarding increase or decrease are based on a comparison between the present status and that given in Buller's *Supplement* (1905), which is the last wholly comprehensive survey of the avifauna, although a much greater amount of evidence concerning a smaller number of species was collected by Drummond in his bulletin, *Our Feathered Immigrants . . . with Notes on the Native Avifauna* (1907). If Buller's statements are correct, then eight endemic species have either increased in one or more localities, or appeared in places where they were hitherto unknown; five have definitely decreased since 1905; and thirty are either easily and obviously maintaining their ground or are in no worse position than in 1905. Four species were extinct long before 1905, chiefly through fires and collectors. Of the remaining twenty-nine endemic species there is insufficient evidence of former status (1905) or present, or both, to venture an opinion. It is, of course, obvious that all the indigenous species should be surveyed, but the general apathy of, or lack of, ornithologists in New Zealand for the last fifteen years, although the number of bird-lovers has apparently greatly increased, has made the record so meagre in regard especially to obscure or rare species and distant localities that insufficient data were available for such a complete review. Moreover, the case of the endemic birds was so much the more urgent, not only on account of their uniqueness but also for reasons to be dealt with later, that even such an inadequate attempt as this paper to put the present position of only these before the ornithological world was felt by the writer to be worth while. Two further reasons for publishing such an admittedly incomplete sketch lay in the fact, firstly, that the position is as yet by no means stable, but changes every year; and, secondly, that the progressive forestry policy now in operation in the Dominion makes provision for the permanent preservation of large areas of native forest which are also sanctuaries for the native birds. It is the writer's firm belief that many of the more highly specialized species, if properly protected by an efficient enforcement of the protection laws, will survive in these areas.

Acknowledgment is here gratefully made for assistance received from practically every bird-lover in New Zealand with whom the writer was able to get into touch. Special acknowledgment is due to the following: first and above all to Mr. E. H. Atkinson, with whom almost every sentence in the paper has been discussed in the light of his lifelong study of and regard for the indigenous birds of New Zealand; Messrs. W. W. Smith, James Drummond, H. Guthrie-Smith, H. Drew, George Shepherd, A. Philpott, F. G. Gibbs, R. H. D. Stidolph, P. Keegan, R. A. Falla, W. R. B. Oliver, H. Hamilton, T. Cockcroft, R. S. Sutherland, Rev. Oscar Blundell, Major R. A. Wilson, and last but not least, to Miss M. C. Norris, who typed this paper at very short notice. My best thanks are due to my wife and Professor H. B. Kirk for reading the manuscript.

In nomenclature the writer followed Mathews and Iredale's 1920 *List* except in two species.

ANALYSIS OF THE CAUSES OF DISAPPEARANCE.

The theories which have been elaborated to explain the disappearance of the native birds are legion. There yet remain, however, many facts which receive no explanation. At the outset it will clear the issue if the problem be divided into its two main aspects—the extermination of the indigenous birds from the settled areas, in which European conditions

have been almost entirely substituted for those of New Zealand; and the disappearance of the indigenous birds from regions which are still unoccupied or yet contain considerable areas of bush. The first case, which is evidently that dealt with by Guthrie-Smith (1921) in his illuminating book *Tutira,* is obviously simple. The solution cannot be better stated than in his own words: "The real cause of the diminution of native birds is easy to give: no creature can live without food and breed without covert; woodland species cannot exist without woodland; jungle and swamp-haunting birds cannot survive without jungle and swamp—they cannot feed on clover and breed on turf. . . . That is the simple explanation of the great decrease of natives."

Throughout the world, of course, the fauna of swamps has been driven out wherever marshes have been drained. The woodland species of New Zealand were peculiarly fitted for the most exclusively sylvan conditions; geologically speaking, only yesterday by far the greater portion of the two Islands was under heavy forest. In spite of this, however, eleven endemic species have adapted themselves so thoroughly to the conditions of actual settlement that they will probably survive. They have achieved a balance with the new environment. With all the other species the balance is still uncertain.

The second case, which deals with the disappearance of indigenous birds from regions which are still unoccupied, is in some respects inexplicable. Not a single one of the theories advanced is able to explain all the facts either in regard to all the species or to any one species. The chief fact which emerges from the chaos of numerous hypotheses and more numerous exceptions is the need for more exact evidence regarding the effects of alien conditions on New Zealand birds. The facts which have not yet been explained are briefly—the disappearance of the robin at an early date from immense areas of almost untouched bush, of the bell-bird from the North Island and its subsequent reappearance there; the practically total dying-out of the kakapo in the North Island before settlement had much more than commenced, and the extreme and early scarcity of the saddleback on the mainland of both Islands, particularly of the North. These and other anomalous cases are treated at length under the species concerned.

The following is a list of the chief factors which have supposedly operated to diminish the numbers of the indigenous birds:—

1. *Total Destruction of Habitat.*—This has been dealt with above, and has been recognized as fully capable of explaining the disappearance of non-adaptable species from settled areas.

2. *Alterations in Food-supply* (Fulton, 1908).—This refers chiefly to disappearance from settled districts, and its consideration has therefore been rendered unnecessary by 1. Other alterations have been effected by introduced animals, which are discussed next.

3. *Introduced Animals.*—Of the known causes, next to actual settlement and clearing this has probably been responsible for the greatest damage. Concerning past errors in acclimatization, Guthrie-Smith (1914) says, in effect, that it is useless to cry over spilt milk. But the indications are that the lesson has not yet been learned; the exponents of the pernicious practice of naturalization are still at large, and the writer feels that every possible opportunity should be taken to express condemnation of the past and warning for the future.

Of the unintentional importations, the black rat (*Mus rattus* L.) has spread from one end of the country to the other, and has been driven into the bush by the later-coming brown rat (*Mus decumanus* Pall.), where it has been accused of nest-robbing on a large scale. The brown species carries on the same evil work in swamps. Buller blamed the rats for the extermination of the bell-bird from the North Island; but the continued presence of the bird in the South Island where rats were also plentiful, the discovery (by Buller himself) of an abundance of the birds on an island in Lake Taupo positively swarming with rats, and, above all, the reappearance and present widespread distribution of the bell-bird throughout the greater portion of both Islands, are facts all hard to reconcile with this theory. Similarly, Guthrie-Smith considers the rat responsible for the scarcity of the robin; but the occurrence of the bird in settled districts in the South Island, and the equal accessibility of the tits' nests (*Myiomoira* spp.) although the latter species are common birds, are facts at variance with such an explanation. The rat theory, however, receives a certain amount of confirmation from the common occurrence, even in thickly populated areas, of the two fantails and the grey warbler, both of which build nests often practically inaccessible to rats.

With regard to stoats and weasels and ferrets, there can be no doubt whatever that, with the probable exception of wekas, all ground-birds, several ducks, and many smaller birds are their easy prey. Earlier reports are almost monotonous in their consistent character: "Weasels and stoats common, kiwis and kakapos disappearing." "Stoats are common from end to end of both Islands" (Thomson, 1922); and reports still come to hand of the damage they commit. Thus Mr. R. S. Sutherland (1922) writes, "I consider the stoat to be the birds' worst enemy." Major R. A. Wilson (1922) says, "My observations down south made me feel sure that the chief actors in the disappearance of the kiwi, kakapo, and suchlike are the stoat and weasel. The stoat and weasel were introduced a good many years ago to combat the rabbit pest, and quite probably the rabbits themselves aid very much in the destruction of the birds by affording a 'living-wage' to the marauders and allowing them to spend their spare time after the birds. At first I thought that the vast forests in Westland would prove a sanctuary for the birds, as it did not seem likely that weasels would find birds scattered over so vast an area." Major Wilson's recent observations, however, showed him that the weasels had penetrated to the most remote and unlikely places, and the only ground-birds of which he had any indication were a few wekas, which can probably withstand this enemy.

Cats, both the more or less domestic individuals in the settled districts and those which in the back country have reverted to a feral condition, are a great menace to most forms of bird-life. Two facts are, however, interesting in this connection. Firstly, the bird most frequently and most easily caught by cats in settled districts is the white-eye—which remains the commonest indigenous bird. Secondly, most authorities have considered these animals highly destructive to the smaller rails; but Guthrie-Smith (1921), arguing from the fact that near houses where cats are kept the nests of various rails are least molested by rats, believes that the influence of cats may at times be actually protective.

Dogs are probably the most dangerous enemies of the weka. Wild dogs, however, are now apparently nowhere very common, while in settled districts gorse forms an efficient protection. To the kakapo and kiwi they

are a destructive factor second in importance only to stoats and weasels. Potts describes diggers' dogs which made a specialty of kiwi-hunting, and ate only the brains of the numerous birds they killed.

Swine were among the earliest of introduced animals—a considerable proportion of those which now range so much of the back country of both Islands being descendants of those liberated by Captain Cook in 1773 (Thomson). Their influence has been both direct, by the actual destruction of ground nests and possibly of young birds; and indirect, by the breaking-down and rooting-up of undergrowth. In this opening-up of the forest and consequent destruction of covert for ground-birds the pigs have been assisted by wild goats, cattle, deer, and other naturalized ungulates.

Man, as an introduced mammal, quite apart from the influences of his actual settlement, has operated as a destructive agent in two ways. Firstly, explorers and prospectors made a practice in the past of living to a large extent on birds such as pigeons, kakas, kakapos, kiwis, and wekas—a more or less legitimate usage which, owing to the magnitude of the area concerned, can have had very little effect on the numbers of the then common species so treated. Secondly, collectors have been responsible for the exportation of incredible numbers of certain species both for allegedly scientific purposes and for the ornamentation of feminine apparel. The rapid decrease of the birds concerned—particularly kiwis—made the millinery export soon unprofitable, but the same cause only spurred on the "scientific" collectors to greater efforts. The present writer has already remarked (1922) that "Buller's tremendous collections, which make his magnificent works so largely a record of massacre, were made, in the opinion of one at least who knew him well, under the firm conviction that the birds of New Zealand were already doomed, and that it therefore behoved every ornithologist to obtain for posterity as complete a collection as possible while there was yet time." That there is still time to preserve them in a far better way is the main contention of this paper. In restricted localities the collector has undoubtedly been a powerful factor in the decrease of the endemic birds: in the case of the huia, stitchbird, and several of the outlying insular species he has perhaps been the predominant one. At the present day there is absolutely nothing to prevent his shooting out rare species in local areas where they have perhaps become successfully adapted to every other alien condition. No one realizes more fully than the writer the importance of type collections; but the fact that the vast majority of the specimens collected in the last century has not only been exported from the country but housed in private collections, while not a single representative public collection exists in the Dominion at the present day, is a sufficient indictment of the practice in the past, and a strong condemnation of its continuance save under the strictest supervision and limitation.

N.B.—This reproach has been in some measure removed now that Canterbury Museum has acquired one of the Sir W. Buller collections.

It is necessary to state that all the above remarks anent the damage wrought by man himself refer to the white man chiefly, and to the Maori only in so far as the immemorial institutions of the latter have been corrupted by civilization. Birds formed a very considerable portion of the food of the ancient Maori; but his exploitation of these, as of all other forest products, was carried on under the most scientific and rigid supervision of the *tohunga*, or priestly expert. The most numerous and

complicated rules were punctiliously observed as religious rites to prevent in any way the disturbance of the bird population, leading possibly to its exodus into the hands of another tribe; while on any signs of fright, diminution, or poor condition the *tohunga* might place under *tapu* either the whole of a certain area or all or certain of the bird species in that area; in addition, no birds might be taken except in their prescribed season. All these restrictions were enforced purely by spiritual authority, acting on a living faith in immediate punishment. The result was in every way favourable to the birds. In respect of efficiency, the protection laws of our own time will bear not the faintest comparison with these game laws of the old-time Maori. Mr. Elsdon Best, who has given the writer most of the above information (though the subject was first brought to the writer's attention by Mr. A. Atkinson), states that it is his definite opinion that the Maori under the ancient regime would never have exterminated a single species. Biologically speaking, man and birds had reached a state of equilibrium. Mr. Best likewise believes that though the stragglers of the moa family may have been killed off by the Maori, it is incredible that the extinction of the Moas as a whole can be laid at their door. Needless to say, *tapu* is now a thing of the past, and the present-day Maori shoots pigeons and kakas in great numbers with no more compunction than his pakeha brethren.

The evidence regarding the effect of introduced birds is extremely scanty. As regards competition for food-supply, they may in a sense be said to have brought their own food with them in the form of cultivated plants and weeds and the insect enemies attached to these. Guthrie-Smith (1921) writes: "Nor will species that disappear do so for the reasons so often assigned: they are not less vigorous than their acclimatized rivals; they will neither be ousted by imported species nor annihilated by imported vermin. Much has been written about the inability of New Zealand birds to withstand the competition of the new-comers; their disappearance has been predicted on account of defective morphology. If this be indeed the case, then other qualities more than atone for such structural deficiency." He here instances a pied fantail hawking in a deluge which was killing wholesale quail, sparrows, and other introduced birds. "Another reason assigned for the disappearance of the natives is inability to compete with alien breeds in regard to food-supply." He then proceeds to show that the indigenous species, with the possible exception of the pigeon, "lay the same number of eggs, breed as frequently per season, and rear as many nestlings as in the 'eighties,' when few aliens had reached the station, when none were abundant. Food has proved ample for both stranger and native." L. Cockayne has long maintained that introduced plants are powerless to affect the indigenous species without the aid of man and man's introduced animals and agricultural implements. A somewhat similar case might be made out for the birds. Few introduced birds have obtained a hold on areas which are not spoilt by settlement. The house-sparrow is an example of an introduced species never found away from settlement. The blackbird and the chaffinch are among the few which obtain a living in practically untouched bush. Even reserves quite close to towns are remarkably free from introduced birds. The writer has in mind one particular area of reserved bush of 60 acres lying only six miles from one of the largest cities of the Dominion. Here alien birds are an absolutely negligible quantity and the indigenes extremely abundant.

From the earliest times, however, it has been considered a matter of course, particularly by such writers as Wallace and Newton, that the imported birds were, so to speak, morphologically and psychologically more up to date and therefore certain to replace the original inhabitants. It is important to realize that no evidence for such a theory exists. Certainly Guthrie-Smith (1910) found starlings dispossessing kingfishers of their nesting-holes, and doubtless other hole-nesting species suffer in a similar way; but so likewise do the starlings' compatriots in England. Introduced birds are said to be more adaptable, but they are adaptable chiefly to the man-made conditions with which in their northern homes they have long attained a state of balance. For every introduced species which has become perfectly adapted to purely aboriginal conditions it is possible to show two indigenous species which have adapted themselves to purely civilized conditions. Naturally, however, those indigenous species which were most perfectly adapted to some one or other restricted portion of the original environment were the least likely to adapt themselves to new conditions. In other words, as the following tables and figures indicate, the birds which have suffered most from the sum total of alien influences are those which are most peculiarly New Zealand.

I. The following endemic species have non-endemic congeneric relatives within the New Zealand region :—

Endemic Species.	Relative Non-endemic.
Eudyptula albosignata	*E. minor.*
Chlidonias albistriata	*C. leucoptera.*
Bruchigavia melanorhyncha	*B. novaehollandiae.*
Himantopus novaezealandiae	*H. leucocephalus.*

Except in the case of the *Chlidonias* species, in which *leucoptera* is extra-limital, and of very rare occurrence in New Zealand, all the endemic species are rare, while all the non-endemic are common.

II. The following endemic genera have non-endemic related genera within the New Zealand region :—

Endemic Genera.	Related Genera.
Megadyptes	*Eudyptula, Eudyptes.*
Anarhynchus, Thinornis	*Cirrepidesmus.*
Nesolimnas	*Hypotaenidia.*
Notornis	*Porphyrio.*
Sceloglaux	*Spiloglaux.*
Myiomoira, Nesomiro Miro, Maorigerygone, Hapolorhynchus	*Rhipidura.*
Anthornis, Notiomystis, Prosthemadera	*Zosterops.*

Except in the case of *Maorigerygone* and possibly *Notornis*, the endemic genera have suffered severely from introduced influences, while the non-endemic genera have suffered either much less or not at all.

III. The following endemic genera have no near relatives elsewhere: *Gallirallus, Apteryx, Strigops, *Acanthisitta, Xenicus, Turnagra, Bowdleria, Mohoua, Certhiparus, *Finschia, Heteralocha, Creadion, Callaeas.* With the exception of the two genera starred, all these have apparently suffered severely from the introduced influences.

IV. Of the nine endemic families, eight, or 89 per cent., have been seriously affected by alien influences. The thirty-eight non-endemic

families include twelve containing only extra-limital species and three (other Tubinares) of wide-ranging species not in a position to be much affected by civilization. Of the remaining twenty-three non-endemic families, some or all of the species in seventeen, or 74 per cent., have been seriously affected by alien influences.

V. Of the twenty-five endemic species which belong to non-endemic genera, twelve, or 48 per cent., have been seriously affected by introduced conditions. Of the fifty-one species which belong to endemic genera forty-two, or 82 per cent., have been seriously affected by introduced conditions.

If, with Cockayne (1921), we differentiate degrees of specific endemism and state that a species which has no near relatives either within or without the area exhibits endemism of the greatest degree, we can obtain from the above statistics the following generalization: *The tendency of a species to disappear under the combined influence of introduced conditions is directly proportional to the degree of specific endemism which it exhibits.* A noteworthy exception to this rule is furnished by the extinct indigenous quail.

Possibly the greatest damage done by introduced birds to the indigenous species is committed in the following indirect way: County Councils, in an effort to abate the small-bird nuisance, pay large sums annually for small birds' eggs. No attempt is made to protect the eggs of native birds from the indiscriminate and energetic collecting to which every small boy in the district is thus incited. Mr. J. C. Andersen informs me of a certain northern agricultural show at which a prize was offered this season for the greatest number of birds' eggs. The winner brought in 3,000, while the total received was no fewer than 11,000 eggs. However much we believe, in the spirit of Deuteronomy 22, that occasional taking of eggs does little permanent harm to the species so long as the parent birds are left alone, such wholesale destruction by one small boy in one small district for a portion of one season only, even if the percentage of native birds' eggs were small, must be a potent factor in the diminution of the indigenous species.

One other feature of the influence of introduced birds on the indigenous species now deserves consideration, since it supplies perhaps the only theory which can even partially explain the wholesale disappearance of certain species from untouched areas either before weasels and stoats were introduced or before they or any other cause of sufficient magnitude had conceivably reached the areas in question. This is the hypothesis of an introduced avian disease which might conceivably commit the same havoc among the indigenous birds as measles among aboriginal races of men. The proof that such a disease does exist in the introduced birds has been supplied by Mr. A. B. Doré, to whom the writer is indebted for full information additional to that recorded in his three papers (1920, 1921) on avian Haematozoa in New Zealand. Varieties of malarial parasites were found in the blood of thrush, blackbird, and skylark, and in the indigenous ground-lark. In the latter bird "plasmodia were similar in appearance to those found in the imported song-thrush" (1920, p. 118). Two separate organisms were discovered, halteridia and plasmodia, the latter by far the more injurious. Mr. Doré states: "The possibility of the imported birds infected with halteridia transmitting these parasites to native birds must be borne in mind . . . Labbe considered the halteridia of different birds to be all one species, but other observers . . . distinguished many species . . . Possibly a given species of halteridia might

infect numerous species of birds. If the halteridia of birds belong to only one species, then infection of native birds should occur if the intermediate* host were present. But, on the other hand, if the species of halteridia were restricted to one or numerous closely related species of birds, infection would probably be observed only if the imported birds were closely related to the native birds" (1920, p. 12). "It would be interesting to ascertain the mortality amongst native birds from this disease. In experiments on 500 canaries E. and E. T. Sergent found that all could be infected by the bite of an infected Culex . . . causing a mortality of 61·3 per cent." (1920, p. 119). Mr. Doré informs the writer that much more work is necessary before introduced bird-malaria can be proven a factor in the disappearance of the indigenous birds. Firstly, the invertebrate host in this country is quite unknown, but is probably a mosquito; secondly, an altogether insufficient number of native birds has been examined. It is reassuring that a prick in the ball of the foot supplies sufficient blood and the bird can then be liberated practically unharmed. That the disease is capable of fatal results is fairly conclusively proved by the experiments quoted above, and by the occurrence of two dead thrushes which Mr. Doré found under conditions which left little doubt that malaria was the cause.

Two species of ticks which were almost certainly introduced have been found on the huia (see section under this species). As Mason (1921) says, commenting on this infestation, "We possess abundant evidence of the destruction caused by members of the Ixodidae in spreading disease and death among the animals they attack." There is here, therefore, further evidence of a possible means by which disease, in this case presumably not malaria, may have been introduced. So much for the influence of the introduced birds.

Trout, which have been introduced in such large numbers in almost every suitable locality, are said to have been indirectly injurious by devouring the aquatic larvae of insects which, when adult, formed food for the native birds. Certainly Tillyard states that more than one species of endemic mayfly has been thus rendered extremely rare. We know, however, so little of the insects preferred by the indigenous birds that such an hypothesis must for the present remain purely conjectural.

With regard to bees, there can be no doubt that their early increase was phenomenal and that their great abundance gave some ground for the belief that the honey they took seriously diminished the food-supply of the native honey-eating birds. Bees, however, are still plentiful, and three of our four honey-eaters are among the most abundant of indigenous birds.

4. *Fire.*—The last cause with which it is proposed to deal here is fire. Fire is one of the most destructive agencies accompanying settlement, and as such is included under cause 1. There are, however, occasions when fire has destroyed large areas of cover, both forest and tussock, in regions where actual settlement was not intended. Moreover, it is the greatest menace to reserves at the present time, and its comparative absence adds to the advantages of island sanctuaries. Fire is usually invoked as the chief cause of the extinction of the quail and of the Chatham Islands fern-bird. The Maori possess a strong and persistent tradition that the moas, whose remains are found in such enormous numbers in swamps at the present

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*Mr. Doré informs me the word "intermediate" should be omitted.

day, took refuge in these damp retreats from vast conflagrations which devastated the country.

Finally, the apparent disappearance of the kakapo from the North Island, and of several species from the Urewera long before settlement could conceivably have affected the rugged mountain regions which formed their haunt—before the importation of alien birds or of weasels and stoats —point to causes as mysterious as those which led to the dying-out of the whole family of moas. The later phenomenon, with the geologically recent disappearance of *Cnemiornis*, *Harpagornis*, and *Aptornis*, links this inexplicable decrease of the kakapo and the quail in virgin areas with the extraordinary extinction of the horse in North America, and with the blotting-out of whole groups which had once been dominant in geologic history.

"So far the best that has been done towards the conservation of species is but negative. At the best man has here and there been content not to destroy utterly. What is required is positive work—the elimination of vermin and parasites, the study and augmentation of special supplies of food, the careful reservation of nesting-accommodation" (Guthrie-Smith, 1921). The same writer advocates the permanent reservation of the Westland National Park, of Stewart Island, and of the Subantarctic Islands. Other potential sanctuaries exist in the ranges of the North Island, where extensive regions are quite unfitted for settlement. To quote once more, and in conclusion (Guthrie-Smith, 1914): "It is on such natural sanctuaries as these that I advocate the efficient protection of our avifauna, and the enforcement of laws excellent in themselves but at the 'back o' beyond' not worth the paper on which they are printed. In its birds each generation has but a life interest; no more than sea or sky do they belong to any period. They are property entailed and to be transmitted age to age inviolate. Their annihilation is in very truth wrong done not to ourselves or in our time alone. Civilization succeeds civilization as do the seasons of our mortal life; cities are razed, and on their ruins others rise; knowledge destroyed can be again attained; but the extinction of species is an everlasting blank—a loss that time itself cannot repair."

We now pass on to consider the seventy-six endemic species in turn:—

Endyptula albosignata Finsch. Silver Penguin; White-flippered Penguin.

Oliver found this species breeding in fair numbers at a South Island locality in 1907. Falla records one specimen without absolute certainty from a northern locality of the North Island in 1918. Sutherland found it in several South Island localities in 1918–19.

Megadyptes antipodes Hombr. & Jacq. Yellow-crowned Penguin; Yellow-eyed Penguin.

Sutherland found small scattered breeding colonies at Stewart Island in 1916. He mentions two South Island localities in which the birds used to nest but do not now do so, although they still frequent the old sites in the breeding season. Guthrie-Smith (1914, p. 58) describes it as common in parts of Stewart Island. Oliver found it breeding on the South Island mainland in 1907.

The Shags.—In spite of the fact that, as Guthrie-Smith says (1914, p. 162), except on his own property "there is no part of New Zealand where the destruction of shags is not thought to be a righteous action," none of the species appear to have become seriously rarer, while the originally common species are apparently as abundant as ever.

Hypoleucus varius Gm. Pied Shag.

This is still the common coast shag in many localities from North Auckland to Stewart Island.

Hypoleucus carunculatus Gm. Rough-faced Shag.

Oliver found this handsome species plentiful in restricted localities in 1922.

Hypoleucus campbelli Filhol. Campbell Island Shag.

Guthrie-Smith (1914, p. 203) found this a fairly common coastal shag on Stewart Island in 1911, where the species was represented by the variety *stewarti* Ogilvie-Grant. Captain Bollons, who has kindly supplied information on the subantarctic birds, states that the type subspecies is still plentiful. The subspecies *colensoi* Buller is also, according to the same authority, quite safe in its unmolested haunts.

Hypoleucus chalconotus Gray. Bronze Shag; Pink-footed Shag.

Guthrie-Smith (1914) records this with the other Stewart Island species, with which he thinks it probably conspecific; at least, he found them almost certainly interbreeding.

Stictocarbo punctatus Sparr. Spotted Shag.

This is a common species in several portions of both Islands. Mr. W. R. B. Oliver mentions that the only two breeding-areas known to him are widely separated, and situated in North and South Islands respectively.

Stictocarbo featherstoni Buller. Chatham Islands Shag.

Mr. H. Hamilton informs the writer on reliable authority that this species still exists.

Chlidonias albistriata Gray. Black-fronted Tern.

Oliver in 1907 found this beautiful tern breeding in at least two of the South Island river-beds. A specimen in the Canterbury Museum was obtained in one of these localities about two years ago. In 1922 and again in 1923 I found it not uncommon in Canterbury.

Bruchigavia melanorhyncha Buller. Black-billed Gull.

This species bred in 1907 in a South Island river-bed. It has also been recorded as breeding at a North Island locality, but the writer believes no specimens were actually compared with the commoner *B. novae-hollandiae* Stephens (mackerel gull), which varies considerably in plumage at different ages. Mr. R. S. Sutherland observed it in several South Island localities in 1913, 1918, 1920, and 1921. "Perhaps now much scarcer than at one time."

Coenocorypha aucklandica Gray. Semi-woodcock; Subantarctic Snipe.

Captain Bollons, in a letter giving the position of all the New Zealand subantarctic birds, states that there is no reason to believe that this species has decreased.

Himantopus novaezealandiae Gould. Black Stilt.

It is extraordinary that I have very little recent information concerning this species. The most plausible explanation is that there are few bird-observers in its haunts. Mr. George Shepherd has a note of it from Canterbury in 1922–23.

Pluviorhynchus obscurus Gm. Dotterel.

Guthrie-Smith (1914) and Philpott (1919, p. 224) mention this species as fairly plentiful on Stewart Island, although seldom seen on the neighbouring mainland (Philpott). Falla (1922) records it as common in the north of the North Island. It occurs probably in suitable intervening localities, but might be easily overlooked by the ordinary observer.

Anarhynchus frontalis Quoy & Gaim. Wrybill.

Mr. G. Shepherd has seen eight specimens in two adjacent North Island localities during the years 1910–17, all singly. No records are forthcoming from the South Island, probably on account of lack of coastal observers. The habits of the bird are apparently such as to elude any but the sharpest observation.

Thinornis novaeseelandiae Gm. Shore-plover; Sand-plover.

It is a matter for regret that no recent records of this beautiful endemic plover are forthcoming. Mr. Hamilton suggests that it may still occur at the Chatham Islands.

Rallus muelleri Roths. Auckland Island Rail.

Buller wrote in 1905, "presumably extinct." Captain Bollons states that practically the only source of information is through the service in his charge, and he sees no reason whatever for Buller's pessimistic opinion.

Cabalus modestus Hutton. Little Chatham Islands Rail; Mangare Rail.

Buller (1905) considered this almost certainly extinct.

Nesolimnas dieffenbachii Gray. Chatham Islands Rail.

This is said to have been exterminated more than sixty-five years ago. Undoubtedly the greatest enemy of these three rails, two of which represent endemic genera, was the collector.

Gallirallus. The Woodhens, or Wekas.

For at least three highly important reasons, which will appear in the sequel, the case of the wekas is one of the utmost interest. Firstly, every bird-lover in New Zealand should read the chapter on the weka in Guthrie-Smith's *Mutton-birds and other Birds* (1914), and particularly the following summarizing paragraph: "If, then, in New Zealand, any serious interest ever comes to be taken in our native birds, the most efficient

method of preserving the smaller tree-breeding species lies in the propagation of the weka. Of all the birds that deserve our care he comes foremost, and assistance withheld from him is help denied to half the indigenous birds of New Zealand." Guthrie-Smith, and many another ornithologist with him, is convinced that in many localities the greatest enemy of the smaller birds is the rat, of which at least two introduced species are widespread and plentiful. The weka is the policeman of the bush, and, like certain proprietary mixtures, is "rough on rats."

The second interesting feature of the weka's case is their phenomenal increase in many widely separated localities before the incredible crime of introducing stoats and weasels was perpetrated. Thus Heaphy (1880) wrote: "The weka, now common about the Hutt Valley, was then (1839) so scarce that for more than three months our naturalist was unable to obtain one, alive or dead, or even to see a skin. I think this singular alteration in the birds' numbers has been noticed in Southland. This bird, although not at all shy, is very pugnacious, and can defend its young from either the rat or the cat, hence, probably, its singular increase." It is now almost extinct in Southland (Philpott, 1914), and occurs no longer in the Hutt Valley. Buller (1877) gives similar testimony: "It is a notorious fact that this species, notwithstanding its feebly developed wings, rendering it quite incapable of flight, is getting every year more plentiful in the settled districts of the North Island. The reason is doubtless to be found in the fact that, while its natural enemies, hawks and wild cats, diminish with the progress of settlement, the cultivation of the country increases its advantages in the everyday struggle for existence. The nocturnal cry of the woodhen is now quite familiar in districts where a few years ago it was quite unknown." Similarly, Hamilton (1886) records a great increase in the previous four or five years in Hawke's Bay. Then came a widespread decrease of wekas in both Islands, synchronizing fairly well with the introduction and spread of weasels and stoats, which were universally believed to be the cause. Thus Buller (1897) says that Morgan Carkeek, after two months in the interior of Marlborough, found wekas almost completely gone, and laid the entire guilt on the weasels and stoats. Smith (1886) also considered these bloodthirsty mammals to be the weka's greatest enemies. Buller (1895) attributed the total disappearance of these birds from Horowhenua and Manawatu to stoats and weasels. Yet Fulton (1908), following Drummond (1907), gave eight North Island localities and one South Island area (in which latter weasels were common) in which, nevertheless, wekas were actually on the increase. Philpott (1914) mentions a correspondent who found wekas completely absent round Lake Hauroko in 1889: in 1910, *although stoats and weasels had become very numerous in the interim*, wekas were very common. In 1912 another correspondent reported them once more completely disappeared from the vicinity of the lake. Mr. F. G. Gibbs writes as follows: "The weka seemed to be extinct for many years, but a few specimens began to make their appearance in 1913 [in several localities]. I have seen them occasionally during the last ten years, but not often." In the Wanganui district, Liffiton in 1889 wrote, regarding the decrease of pheasants, "The primary cause is, I think, the great increase of the weka and the predilection these birds have acquired for eggs." He goes on to show that when the pheasant was first introduced there the Maori was living in his old-time way, with

scattered settlements infested by half-starved dogs, which ate the wekas and kept them in check. The Maori took to more civilized conditions and dispensed to a large extent with his canine retainers, while at the same time the extensive planting of gorse hedges gave to the weka impenetrable cover from such of his enemies as remained. To the sorrow of the cultivator the gorse hedges, with the acres and acres of gorse thicket to which they have given rise, have remained in the Wanganui district, and the weka till 1919 was one of the most plentiful of native birds. The extensive gorse areas and the swamps of the gully-bottoms enabled the species to dispense almost entirely with such native bush as was permitted to remain. In this same district in 1900, in 1905, and as far back as the writer can ascertain, wekas were still extremely plentiful. In 1919 there came a rather sudden decrease—a decrease far too sudden to have been the work of weasels, which have been in the district for many years. Finally, Guthrie-Smith (1914, p. 161) writes as follows: "In 1911, whilst walking between the head of Te Anau and Sutherland Falls, I found wekas everywhere very plentiful, not in pairs only but sometimes as many as five grown birds together. . . . Now, it is quite improbable that the weasel tribe should have spared the weka—a ground-bird, be it remembered, and unable to fly. Either, therefore, the amount of damage done by stoats and weasels has been exaggerated, or of late years they have become less numerous; the latter alternative is by no means unlikely, for many aliens, to my personal knowledge, after at first an immense increase in a restricted area, later have spread over the countryside, and in some cases eventually disappeared. A third possibility is this: that by chance I may have passed through an irruption of wekas, similar to that which at Tutira has in my time more than once occurred." The writer firmly believes, and is supported in his belief by such an experienced observer as Mr. W. W. Smith, that all the evidence points to Guthrie-Smith's third possibility as the true explanation of these strange comings and goings of the weka. It seems, therefore, almost certain that, while powerful factors such as the complete destruction of cover by the cultivation of flat country, and the deadly work of weasels and stoats in the few years immediately following their importation, practically exterminated the wekas in restricted localities or decimated its ranks for certain periods, at the same time there have been and are occurring wholesale migrations of all the wekas of a given district. This is the third feature of interest in the weka's case.

With regard to the influence of stoats and weasels on wekas, the evidence is conflicting in the extreme. The unanimity of the early reports soon after the establishment of stoats and weasels renders it difficult to avoid the conclusion that in certain localities these animals practically exterminated all the flightless birds. There is, however, a great lack of evidence by eye-witnesses of slaughter by stoats and weasels. Mr. E. H. Atkinson described a case in which he heard the cry of a weka and found the bird sitting on its nest and a weasel in the act of attacking it from behind. On the other hand, there is more recent evidence of the weka's ability not only to withstand but even to conquer the weasel in a stand-up fight. Thus Thomson (1922, p. 74) writes: "Mr. H. Drummond has accumulated some evidence as to the killing of weasels by wekas (*Ocydromus* sp.). In 1909 Mr. Murrell, jun., and Mr. Harry Birley described how the wekas had been seen attacking and killing weasels. Mr. Murrell witnessed a most interesting fight between them on a path. The weka

circled round the weasel, watching a chance to spring in and strike it, which it did, always on the head, finally stretching its opponent out. In 1916 Mr. A. T. G. Symons, of Christchurch, recorded the fact that wekas were killing weasels." It must therefore be apparent that either the wekas have learned by sad experience to combat the weasel, or else the disappearance of the weka from localities soon after the ingress of the vermin therein was a mere coincidence due to one of the wholesale migrations evidence of which has been elsewhere recorded. Of these the first alternative seems the more probable, since other flightless species also disappeared. In 1901 Mr. E. H. Atkinson found at Wanganui in one afternoon six weka's nests with eggs sucked by stoats or by rats; yet in that district wekas remained one of the commonest birds for eighteen years after that date.

To sum up, the weka, as a destroyer of rats and weasels, is of the utmost value to the other native birds. Its relation to the introduced mammalia is as follows: Against weasels (and possibly stoats) it is now able to hold its own; rats and mice are its prey; pigs probably destroy the nests, but evidence is required; cats, though said by Buller to be its greatest enemies, by other observers are considered not able to tackle a full-grown weka; and, finally, dogs readily kill both adults and young, but against these enemies gorse coverts form an entirely efficient protection. In weka-frequented country cats are repeatedly bringing in specimens of the smaller rails, and even of the landrail; but no case is known to the writer of a weka forming the prey. At the present day, therefore, there seems no valid reason why the weka should disappear from districts either in bush or under settlement, provided there be plenty of cover. Finally, the numbers of the weka population in many widespread districts have oscillated to such an extraordinary extent, and from such early dates, that an explanation in terms of successive extinction and recolonization from without is almost incredible. The hypothesis of wholesale migrations or exoduses seems to fit the facts best, especially in view of the usual suddenness of the appearances and disappearances.

The movements of the wekas will be better understood by reference to the following chronological data for selected districts. All the following facts and the previous discussion refer exclusively to the common North and South Island wekas, *G. australis* vars. and *G. hectori* respectively. The writer is not aware of any similar records in the case of the black woodhen (*G. brachypterus*). As the respective ranges of the two former species are by no means exactly ascertained, no attempt has been made to separate them.

Movements of Wekas.—Wellington District: 1839—none (Heaphy); 1880—common (Heaphy); 1883—first ferrets liberated (Thomson); 1885—first stoats and weasels (Thomson); 1888—very abundant (Buller); 1907—gone except one locality (Drummond); 1922—none (Myers).

Lake Hauroko (Philpott): 1885—stoats and weasels liberated, mostly in Southland; 1889—apparently none; 1910—very common, stoats and weasels very numerous; 1912—disappeared.

In the following case there was a sudden decrease long after stoats and weasels had become common. Wanganui district: 1888—common, increasing (Liffiton); 1901—common (Atkinson); 1905—common (Buller); 1912–18—common (Myers); 1919—decreasing rapidly at least in one locality (Myers).

Kaipara district: 1855—a few still linger (Buller); 1888—for thirty years never met with in far North (Buller); 1907—all native birds decreasing

except wekas (Drummond); 1923—weka occurs throughout North Auckland wherever suitable cover (Myers).

Tutira, Hawke's Bay (Guthrie-Smith): 1885—increasing; 1886—increasing in Hawke's Bay (Hamilton); 1896—decreasing; 1909—common; has more than held its own during last twenty-five years; numbers fluctuate very considerably; 1921—"will survive for ever in the gorges"; 1922—"altogether gone."

A Nelson Province locality (Philpott): 1920—one heard; 1921—one seen; 1922—four or five seen; also much commoner in a neighbouring locality.

In the North Island at the present time (1922) wekas are still numerous over fairly large regions; but in some localities they are diminishing. From one locality in which they have remained consistently numerous or even increasing (1907) a correspondent wrote to the *New Zealand Journal of Agriculture* in 1918 to say that he is "troubled with wekas and wishes to know the best way to get rid of them." Across the strait, Mr. Philpott gives one province in which wekas are increasing. His data are given above. He writes, "One striking thing I have noticed in connection with this bird — it is far more wary than formerly . . . It is rare for one to visit the tent or hut. I think this new wariness is shared by the parrakeet and to some extent by the robin, and if it is a fact it may prove the salvation of those species which adopt it." In this connection it should, however, be mentioned that two wekas seen by the writer in the Nelson District in 1923 were as tame and inquisitive as in the old days.

Stewart Island remains a safe refuge, where it is still fairly common (Philpott). In the far North, wherever cover is afforded by bush, by swamp, or by gorse, the weka is common.

Gallirallus australis Sparr. Brown Woodhen, or Weka.

Gallirallus hectori Hutt. South Island Woodhen.

All the data available regarding these two species, whose ranges are difficult at present to distinguish, are summarized in the previous section, which deals with these two species only. Neither is likely to become extinct, although prophecy concerning species whose past history exhibits such extraordinary disappearances or reappearances is probably highly unsafe. They have certainly treated with scant respect the prediction of one who knows them far better than the writer can ever hope to do. Guthrie-Smith (1921), referring to the weka and the kiwi, said, "These two highly interesting ground-birds are safe on Tutira should the whole of the rest of New Zealand be turned into cabbage-gardens cultivated by Chinese." In 1922 the weka had "altogether gone" from Tutira!

Gallirallus brachypterus Lafres. Black Woodhen.

Philpott (1919, 222) gives an illuminating account of the ups and downs of this species. In the mining days "many were killed for food, and many more were destroyed needlessly by the miners' dogs." In 1911, when mining activity had practically ceased, the black woodhen was already increasing. Up till 1918 it was increasing in numbers and in range. Since then there has been a plague of mice in the district, and the wekas "were snapping them up on every opportunity." This abundant food-supply gave an additional impetus to the increase of the species. The range of this

distinct species is comparatively limited; but according to Philpott it is a remarkably enterprising bird even compared with its brown cousin of the South, and, judging by the above data, may be considered safe.

Notornis hochstetteri Meyer. Takahe.

One of these birds was reported to have been seen in full view on a track near Lake Te Anau so recently as 1914. Secretary Island, on which the second specimen was caught, was recently (1923) declared a sanctuary.

Poliocephalus rufopectus Gray. Little Grebe; Dabchick.

This species probably eludes observation in many localities where it is not uncommon. Falla reports it as rare in a northern locality in 1921, while Philpott (1914) states that it probably occurs on many of the lakes and lagoons of the south-west portion of the South Island. Guthrie-Smith (1921) believes that, at any rate on his property, no fears need be entertained for the survival of the dabchick.

Apteryx australis Shaw and Nodder. Brown Kiwi.

The brown kiwi is one of the species which Guthrie-Smith considers will always maintain itself in the broken country on his run in Hawke's Bay. The same authority (1914) found it, or one of its races, in Stewart Island, where also it was rather scarce in 1916 (R. S. Sutherland). The latter met with it on the west coast of the South Island in 1922. Mr. P. Keegan assures me that it is still plentiful in the Urewera, while Mr. R. A. Falla gives an Auckland (1920) locality. On the North Auckland Peninsula one of the surprises of this investigation was the discovery of the species *in plenty* no farther than five miles from one of the larger towns. Here it occurred in the bush which capped the peaks of the hills, while the valleys and flats had been long settled and bore no bush.

Mr. H. Drew has kindly given me particulars of the appearance in 1921 of three kiwis in one of the most thickly populated suburban areas of a large North Island town, at least six miles from the nearest scrap of bush, although extensive raupo swamps are near. The first, a female, appeared in July. She was captured and kept in confinement, where she became quite tame. At night, and especially before rain, her calls might be heard from a considerable distance. After some months an answering call was heard from perhaps a mile away, and in December, when the second call had been heard on many different occasions, a male kiwi was seen at the cage, attempting to get in. Since then another kiwi has been seen in the vicinity. Mr. Drew is at a loss to account for the appearance of kiwis in such an unexpected locality; but he favoured the idea that they may have escaped from captivity. The following facts, however, lend colour to the view that they may be genuine wild examples: (*a*.) Mr. Drew can hear of no one in the locality who possessed three kiwis. (*b*.) It is hardly probable that the birds would have escaped at considerable intervals, as the lengthy periods between their successive arrivals would seem to indicate. The birds could hardly remain long undetected in such a thickly populated neighbourhood. (*c*.) The writer himself can vouch for the occurrence of a kiwi less than two years ago in a remnant of native bush about five miles on the opposite side of the same town.

The *Dominion* newspaper for the 7th October, 1922, reports a kiwi "recently accidentally killed within ten miles of Napier." These three

reports from country which has long been settled are of great interest in connection with Buller's remark regarding this bird, written in 1865: "It has long since disappeared from the inhabited country." The North Island kiwi is reported plentiful at three more North Island localities. The area covered by my correspondents is an infinitesimal portion of the whole. Since the above was written Mr. Philpott has told me another South Island locality where the bird is plentiful (1922). In the North Auckland district dogs are perhaps the greatest enemy.

Apteryx oweni Gould. Little Grey Kiwi; Rowi.

Three localities are reported in the South Island where this small species still occurs. It has undoubtedly disappeared from apparently suitable localities; but I think the lack of reports is largely due to paucity of observers in the South Island.

Apteryx haasti Potts. Great Grey Kiwi; Roa.

Judging from the scanty reports, this is still the rarest of the three species of *Apteryx*. Mr. R. S. Sutherland gives one South Island locality where it may be occasionally seen.

Coturnix novae-zealandiae Quoy & Gaim. Quail.

This has, of course, been extinct for many years. I mention it merely to complete the list and to note that the introduced Australian swamp-quail (*Synoicus australis* Temm.) is still frequently reported as this species, especially in the far North, where the introduced bird is common. The disappearance of this species from primitive areas untouched by fire or settlement remains one of the mysteries of bird-extinction.

Hemiphaga novaeseelandiae Gm. Pigeon.

This magnificent bird is still distributed from North Auckland to Stewart Island, practically wherever there is sufficient bush to support him. Guthrie-Smith (1921) includes him among those species which will always survive in the precipitous gorges of his Hawke's Bay run.

The pigeon has apparently learnt no caution, and still presents its fair white breast as an irresistible target to any thoughtless fool behind a gun. The greatest destruction of the species at the present day is, however, the work of Maori and white man in the back country where bird-protection enactments are either a mere name or even totally unknown. Large numbers are still shot every season. Efficient policing of forestry and scenic reserves should, however, be the only requisite for the permanent preservation of this most beautiful bird. The writer knows no species which responds more readily to protection.

Hemiphaga chathamensis Roths. Chatham Islands Pigeon.

I have no recent news of this species. A natural-history survey of the Chatham Islands is an urgent necessity.

Casarca variegata Gm. Paradise Duck.

The largest of the New Zealand ducks occurs plentifully in many widespread South Island localities, and sparingly in several North Island ones, especially on the east and south coasts of the latter. Guthrie-Smith

(1921) mentions this among the species which have actually been attracted to his run in Hawke's Bay by the changed conditions consequent on settlement. It bred there for the first time in the memory of man in 1917, and has continued to do so yearly ever since. Buller (1905) spoke of its decrease then as due to its eating poisoned grain laid for rabbits. Mr. Philpott says, "It seems pretty certain that this bird will continue to hold its own in retired parts (at low elevations)."

Elasmonetta chlorotis Gray. Brown Duck.

This species, which is less dependent on large sheets of water than are any of the other species, is not very frequently recorded by ordinary bird-lovers. It is, however, fairly generally distributed. Guthrie-Smith (1921) considers that it will always survive on his run in Hawke's Bay wherever undrainable marshlands and boggy creeks remain. In two widely separated localities on the opposite (west) coast of the same Island it is not uncommon (1914, 1915). From a neighbouring district Major Wilson (1922) writes that it is rapidly disappearing if not already gone. In the far North it is decreasing considerably, and should certainly be no longer shot, at least for some seasons. The fact that it is protected apparently makes little difference.

Nesonetta aucklandica Gray. Auckland Islands Duck.

Captain Bollons sees no reason to suppose that the numbers of this bird have diminished since its discovery.

Hymenolaimus malacorhynchus Gm. Blue Duck; Mountain Duck.

This beautiful and characteristic species maintains itself wherever the mountain-creeks which form its home are undisturbed by the too near approach of settlement. From one South Island alpine locality it has apparently disappeared within the last two years, although the slight increase in settlement would seem altogether inadequate to change the environment to the extent this extinction would imply. The writer can suggest only that it offers by its tameness altogether too tempting a mark for Sunday idlers animated by nothing but a primitive lust to kill. Guthrie-Smith (1921) believes that the blue duck will for ever maintain itself in the almost inaccessible gorges which form such an attractive part of his Hawke's Bay run. With the permanent segregation and efficient protection of forest and scenic reserves, the perpetual survival of the blue duck should be assured. Most certainly its present position does not confirm Buller's (1905) complacently dogmatic statement that "this is one of those recluse species that must ere long disappear entirely."

Fuligula novaeseelandiae Gm. Scaup.

No fear of the diminution of this attractive little species need be entertained. As Guthrie-Smith (1921) has pointed out, its preference for large and open sheets of water and the situation of its feeding-grounds on the floor of lakes often far from the shore combine to leave only one vulnerable point in the life of this duck. This point is its almost invariable choice of a nesting-site near the water's edge, usually in *Phormium* clumps. The great versatility displayed, for example, by the grey duck (*Anas superciliosa* Gm.) in selecting a spot for its nest is undoubtedly an important factor in the dominance of the latter species.

Promergus australis Hombr. & Jacq. Auckland Islands Merganser.

Captain Bollons states that this was never a very common species and that its numbers have apparently not diminished.

Demigretta matook Vieill. New Zealand Blue Heron.

On rocky coasts the blue heron is generally distributed in both Islands. In many localities it is decidedly abundant even in the close vicinity of large ports. Islets and stacks form often practically inaccessible nesting-places. In at least one locality it appears to be increasing.

Nesierax novaehollandiae Gm. Quail-hawk.

Of our debatable two species of falcons, the larger one, of which we now treat, is undoubtedly the rarer. Already in 1905 Buller spoke of it as "becoming one of our rarest species." Only one authentic record has been available: Mr. W. W. Smith saw one towards the end of 1919 chasing sparrows in a public garden near the centre of one of our largest North Island towns. Had the observer been any one else in New Zealand the writer would have ascribed the bird to the following species.

Nesierax pottsi Mathews and Iredale. Bush-hawk; Sparrow-hawk.

Nowhere very common, this fierce little falcon is very generally distributed in both Islands. The wooded ranges of many parts of the southern half of the North Island probably still maintain as many individuals to the square mile as in the past. Guthrie-Smith (1921) considers that this species has actually gained by settlement on his run, owing to the tremendous addition made to its menu by introduced birds. There some five or six pairs breed on about 20,000 acres.

Spiloglaux novaeseelandiae Gm. Morepork.

Fulton (1908) wrote, "The New Zealand morepork's cry will soon be heard no more." This was surely premature. Not only is the morepork still plentiful where sufficient bush remains to give him shelter, but he has even in some localities adapted himself to the conditions of settled areas to such an extent as to dispense altogether with native forest even in the breeding season. In a long-settled South Island locality the morepork is recorded as breeding in thick cypress hedges, while in the capital city itself the writer has heard him three times during 1922 not more than five minutes' walk from the most congested areas. Guthrie-Smith (1921) considers that on his Hawke's Bay run settlement has benefited the morepork by increasing his food-supply.

Sceloglaux albifacies Gray. Laughing-owl.

Mr. Clouston reports this species from one South Island locality. No other first-hand or reliable information is available. The undoubted diminution in the numbers of the laughing-owl is usually ascribed to the practical extinction of the "Maori" rat. Mr. R. H. D. Stidolph has drawn my attention to the probable fallacy of this argument. Most competent authorities believe the "Maori" rat, which is usually the widespread Polynesian *Mus exulans* Peale, to have been introduced into New Zealand by the Maori. It could not, therefore, have been the laughing-owl's original food. W. W. Smith, one of the few ornithologists

who ever had personal knowledge of this owl, ascribes (Buller, 1871) its "final extirpation" to the weasel. It is hardly necessary to mention that the rugged haunts and nocturnal habits of the laughing-owl would help it, in a large measure, to escape observation.

The disappearance of the species from the North Island is attended with considerable mystery. Fairly plentiful in the Urewera, the least spoilt and most central fastnesses of the North Island in 1855, it became totally extinct there long before the introduction of weasels had been suggested (Best, 1909). Speculation would be fruitless in view of the vast numbers of airy hypotheses which have been woven round the disappearance of the endemic birds. There seems no valid reason why the laughing-owl should not exist and continue to maintain itself in spite of Buller's opinion (1905) that it was "on the verge of extinction."

Strigops habroptilus Gray. Kakapo.

After the introduction, in the middle "eighties," of stoats and weasels, the future of the large flightless owl-parrot looked indeed black. T. Kirk (1896) said its near extinction was "absolutely certain." G. M. Thomson (1922) quotes two cases in which kakapos were practically exterminated in a Westland and in a south-west Otago locality in 1890 almost immediately ferrets and weasels became established. Yet even Buller as late as 1905 admitted that it was still plentiful in wooded country on the west coast of the South Island. In 1907 Mr. R. S. Sutherland found it "moderately plentiful" in certain localities in south-west Otago, but in the same places in 1920 it had apparently disappeared. In 1914 (Philpott) there was recorded one locality in which the kakapo was "not uncommon," while at the present time (1922) there are at least two areas in which it is fairly plentiful. These three South Island localities happen to be as far apart as they could possibly be; and yet "Stoats are common from end to end of both Islands" (Thomson, 1922). The inferential possibilities are two—either the weasels and stoats are not responsible for the diminution of the numbers of the kakapo, or the bird has adapted itself against the enemy. In view of the positive opinion of observers on the spot as to the effect of the weasel tribe on kakapos, possibly the last explanation is the correct one; but support to a theory which considers the main cause of the decrease of this species unknown is afforded by the mysterious disappearance of the bird from the North Island. Elsdon Best (1909, 1910) states that it used to be very common till 1850 in the rougher parts of the Urewera country. It disappeared, however, soon after the landing of the Europeans on the shores of New Zealand, and long before any settled near the district. From the Tararua and other ranges the same authority states that it died out about eighty years ago. Drummond (1912), basing his opinion on evidence supplied by Best and by Maoris, stated, "Evidently at one time they were fairly plentiful in a large part of the country before the arrival of Europeans. I am unable to supply any theory as to the cause of their disappearance, which is a mystery." Apparently only one North Island specimen was examined by Matthews and Iredale (1913), and the writer knows of no ornithologist who has seen a kakapo in this Island, although there have been persistent reports from Maoris in at least two large and "likely" areas. Major R. A. Wilson, in a very informative letter (1922), states that he and Mr. B. C. Aston were convinced that they heard a kakapo near their camp in one of the above localities. Major Wilson writes also, "A

reliable observer informs me he saw a kakapo . . . a few years ago" in another North Island locality. Since the above was written Mr. Philpott states that they must be now extremely rare in one of the South Island localities included above, since in a week he saw practically no sign.

Cyanorhamphus novaezealandiae Sparr. Red-fronted Parrakeet.

Philpott (1919) states that this species, so far as south-west Otago is concerned, still occurs far back in the great timbered areas, but is much more timid than in the old "shanghai" days. Now it is difficult to get within gunshot. "Possibly this acquired timidity will prove the salvation of the species." The remarks of this careful observer apply with equal accuracy to the great forest areas of the North Island, where this species is widely spread and sometimes quite plentiful.* Guthrie-Smith (1921) believes that neither the parrakeet not the kaka can survive without large areas of forest. Even if this be true—and the present distribution indicates that it is—the maintenance of considerable areas of forest under the progressive forestry policy now operating should ensure the safety of the species.

Cyanorhamphus auriceps Kuhl. Yellow-fronted Parrakeet.

Philpott's (1919) notes regarding the red-fronted species apply equally to this, as also do the writer's, although in the North Island the former is certainly the commoner. Guthrie-Smith (1914) records it from Stewart Island and islets. Philpott found it in a Nelson locality in 1923.

Cyanorhamphus malherbi Souance. Orange-fronted Parrakeet.

Philpotts (1919) states "in all probability extinct" in south-west Otago. In some cases it is doubtless confused with the yellow-fronted species; but it has apparently never been plentiful within the historic period.

Cyanorhamphus unicolor Lear. Antipodes Island Parrakeet.

Captain Bollons writes (1923) that this species is quite numerous.

Nestor meridionalis Gm. Kaka.

Philpott (1919) notices that "the smaller forests are now practically forsaken by this interesting parrot." Guthrie-Smith (1921) also considers large areas of forest necessary for its survival. The same author's admirable account of the nesting-hole (1914) seems to indicate that hollow trees with *all* the necessary qualifications must be few and far between. The kaka is now widely distributed from North Auckland to Stewart Island, and occurs also on several islets. As in the case of the pigeon, though possibly to a slightly less extent, the kaka is still largely shot for food in the back country of both Islands by Maori and pakeha alike. All the indications are that the kaka, once decently protected by something more than the letter of a law that is little else, will survive and even increase in the larger forest and scenic reserves.

Nestor notabilis Gould. Kea.

Like the shags and the harrier, which also have (or have had) a price upon their heads, the kea is easily holding its own. This result, which

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* On several islands the bird is still abundant.

it is difficult for an ornithologist to deplore, must be ascribed in great part to the frequent inaccessibility of the kea's nesting-site. Philpott (1919) writes that it is "common on the Hunter Mountains, where its numbers seem to be on the increase." In this locality, on the testimony of a sheep-farmer, it is not interfering with the sheep. The recent removal of the protection afforded to the kea as to all native birds in the Mount Cook scenic reserve indicates that the grasping utilitarianism which dictated the introduction of stoats and weasels into this country is still as powerful as ever. The kea has recently appeared in the Nelson District (Philpott).

An interesting point regarding the kea, and not apparently noticed in ornithological literature, is its occurrence in the North Island. Elsdon Best (1909) states that the Maoris give abundant evidence of its former occurrence in the Urewera, from which district it apparently disappeared before the advent of Europeans. They describe it as smaller than a kaka, brown or reddish, with a "different beak, and state that it lived in the open country."

Acanthisitta chloris Sparr. Rifleman.

Owing to the uncertainty regarding the species denoted by the term "wren" as used by the average observer, many records which may apply to this species have been left strictly alone. In the Wellington District the grey warbler (*Maorigerygone igata* Quoy & Gaim.) is often referred to in popular parlance as the "native wren." Fulton (1908) states that the "rifleman and bush wrens abound wherever are our native trees." This certainly does not apply to the North Island, where the rifleman is confined almost entirely to beech forest, chiefly subalpine, though descending to sea-level where this type of forest does so, while *Xenicus longipes* Less. appears to be confined absolutely to subalpine beech forest. In the South Island, however, Fulton's statement in so far as it applies to the rifleman is apparently correct. Thus Philpott (1919) describes it as "plentiful in all forests and extending to the bush-level on the mountains." The writer has also a record of the rifleman's occurrence in small *Pinus* plantations in another South Island locality. If the above differences between the habitat in the two Islands be borne in mind it may be stated that the rifleman is plentiful in all suitable localities from the centre of the North Island to Stewart Island. North of these limits it is said to occur (Oliver, 1922) on Little Barrier Island.

Adjacent settlement seems to affect the rifleman but little. Doubtless the frequently minute size of the nesting-hole when in trunks is a strong factor in the bird's survival.

Traversia lyalli Roths. Stephen Island Wren.

No reports of the Stephen Island wren have been recorded since its supposed extinction by lighthouse-keepers' cats soon after its discovery.

Xenicus longipes Gm. Green Wren.

Brough, as quoted by Buller (1895, p. 138), stated that wrens had been exterminated in the Marlborough District by stoats and weasels. This apparently referred to both this and the next species. The former authority (Buller, 1905) considered also that the greatest enemies of wrens were cats. The green wren seems never to have been very plentiful in any North Island locality; and here at least there is no indication that there

has been any decrease in its numbers or limitation of its range. Confined to subalpine beech forest, it practically never contacts actual settlement. It is recorded from four North Island localities very widely spread, and from three South Island localities equally widely spread. It is doubtless sometimes confused with the rifleman, which occurs commonly in the same areas, and with which it may be dumped under the uncertain title of "wren."

Xenicus gilviventris Pelz. Rock-wren.

On the authority of Mr. E. H. Atkinson and Major R. A. Wilson, and the writer, this easily overlooked species is recorded from three localities in the Southern Alps. Probably none of our birds come in touch with settlement less than this; nor does its habitat presumably offer any inducement to such colonists as cats and weasels.

Myiomoira macrocephala Gm. South Island Tomtit.

Speaking of south-west Otago, Philpott (1919) stated that this bird is "certainly holding its own wherever the native forest is still standing. It is equally common in the *Nothofagus* forest at 3,000 ft. and the mixed forest at sea-level." From other reports and from the writer's personal observations the same is true of the greater portion of the South Island. Guthrie-Smith (1914) found it common on Stewart Island.

Myiomoira toitoi Lesson. North Island Tomtit.

As early as 1886 Reischek (p. 101) included this species in a list of birds extinct or extremely rare on the mainland. It is now common not only on the island sanctuaries but in a large number of widely separated localities, in many of which and over considerable areas it is the most abundant native bird. The clearings still scattered with charred stumps on the foothills of the ranges are a favourite haunt, while in winter, in orchards and gardens, it achieves complete independence of the native vegetation. Guthrie-Smith (1921) considers it absolutely safe on Tutira, and the same may be said of most of the forested areas of the North Island and of many settled districts where remnants of bush or scrub remain in gullies, swamps, and gorges. The prime factor in the decrease of the robin is often said to be the accessibility of its nest to vermin. The nesting-site of the tit is open to the same dangers to precisely the same degree, yet the bird is abundant.

Nesomiro traversi Buller. Chatham Islands Robin.

Buller (1895) stated, on the authority of Hawkins, that this bird was extinct.

Nesomiro dannefaerdi Roths. Snares Island Robin.

Captain Bollons states that this species is still plentiful.

Miro australis Sparr. South Island Robin.

Fulton (1908) recorded eight localities where this species was common, in one at least of which weasels were known to have obtained a fair footing. Philpott's account (1919, p. 217) of the present position of the South Island robin in south-west Otago is so clear that it must be quoted *in extenso:*

"In considering the problem of the diminution in numbers of New Zealand birds the case of the South Island robin offers some peculiar features. While the bird has disappeared from large areas remote from settlement, it is still to be found in several districts in close proximity to farming, mining, and timber-working activities. Though the coastal forest from beyond the Waiau to Preservation Inlet—many hundreds of thousands of acres—does not now apparently contain a single robin, the bird still holds out in certain localities comparatively close to towns. If the stoat and weasel were alone responsible for the scarcity of the robin we should expect to find outlying districts more favourable to its safety; certainly the writer's experience is that the stoat is much more common in the neighbourhood of cultivation. From 1914 to 1917 I visited the Hunter Mountains each year in January, ascending through the Titiroa Forest from Monowai Flat. In 1914 the robin was common in the lower bush; in the following year only a few were about; on the third trip only a single bird was heard, and in 1917 there was no sign of the species at all. I am unable to suggest a reason for such rapid disappearance. On the Monowai Flat rabbits are very plentiful, and cats and stoats are probably not uncommon. The part of the Titiroa Forest in question is attached to Sunnyside Station, and the owner, Mr. H. Cuthbert, informs me that nearer the homestead the robin is still to be found. In Stewart Island in 1913 I found the bird plentiful on Rakiahua and Table Hill, but it is not in evidence near Half-moon Bay and other settled districts."

Guthrie-Smith (1914) found it plentiful on islets off Stewart Island. But "wherever a man builds the smallest hut and wherever the weka is killed out, rats follow, and the robin is at once exterminated." This affords a typical example of the conflicting statements one obtains in collecting evidence regarding the disappearance of the native birds. In one place the robin is found in untouched bush but not near settlement, and a beautiful theory is elaborated to explain this. In another locality precisely the opposite holds—the bird has disappeared from the back country but is comparatively plentiful in several cultivated areas. One can only deduce from this that the factors of survival are so complicated that generalizations which do not take into consideration the whole known range of the species are valueless. The writer himself can record the robin from two South Island localities besides those mentioned by Philpott, and it is curious to note, after what has been written above, that one of these is a region which has been settled from the earliest days and is practically devoid of bush for many miles, while the other is near the centre of one of the least-touched areas of heavy bush in the whole South Island. To sum up, the present distribution of the South Island robin is very wide, and in some localities the bird is still plentiful, although Buller (1905) wrote that it was almost extinct in 1903.

Since writing the above, the author has received from Mr. Philpott records from two other South Island localities. In one of these the ground was completely cleared by fire and is now covered by a young forest of *Weinmannia*, showing that the robin will come back.

Miro longipes Lesson. North Island Robin.

Buller (1905), in a pathetic lament, speaks of the "last-heard-of pair of this expiring species" seen near Levin. In the same work, however, he admitted it was fairly plentiful on certain islands now sanctuaries. This species, like its near relative on Stewart Island, apparently never

occurs anywhere near settlement. In a certain mountain-range it was plentiful in 1911 (Mr. E. H. Atkinson); but since the locality has been a resort for trampers, who have in no way violated the sanctuary, it has completely disappeared, at least from the vicinity of the track. The writer has records of its occurrence at present in four mainland localities, besides the two islands on which it is still plentiful. All these places are fairly remote from settlement. Major R. A. Wilson writes, "The robin is considerably scarcer, but is still widely distributed, being found [in three localities] and many intervening localities," So far, then, it appears as though the disappearance of the North Island robin were one of those simple cases readily explicable by the influences of approaching settlement, or of the rats which follow in a tramper's track and are attracted by his huts. The anomalous facts are, however, yet to come. Guthrie-Smith (1921) includes this among the species which had disappeared from the area afterwards his run, before settlement in the district had commenced. Similarly, Elsdon Best (1909) states that robins had practically disappeared from the Urewera many years ago, presumably before settlement could have had much effect on this still unsettled area, although the species was numerous there in pre-European days. In the summer of 1901–2 they reappeared in limited numbers in the same region. It is difficult to believe that the accessibility of the nest is the cause of the robin's diminution, when the nest of the two abundant tits (*Myiomoira* spp.) is open to exactly the same dangers. In any case the facts seem to indicate that the North Island robin will be safe in scenic and forestry reserves.

Maorigerygone igata Quoy & Gaim. Grey Warbler.

Philpott's remarks (1919) that "the grey warbler is the bird which I think will adapt itself to the new conditions attendant upon the settlement of the country" are, it is believed, true for the length and breadth of New Zealand. Not only is manuka scrub, which in some localities may be called a native weed association, a favourite haunt of this species, but in many places it has achieved complete independence of all native vegetation. The nesting-place among slender twigs often inaccessible to rats may be a strong factor in the survival of this bird, although, as Philpott (1919) remarks, the "nest does not, as is popularly imagined, hang suspended from a twig, but is securely stayed in position, one or more stout sprays passing through the thick lower portion."

Hapolorhynchus albofrontatus Gray. Chatham Island Warbler.

Buller (1905) wrote that this beautiful and very distinct form was "on the borderland of extinction, if not already gone." It is well, however, to bear in mind two facts: firstly, the frequency with which Buller's prophecies of the speedy extinction of other species have proved utterly fallacious; and, secondly, the large area of the islands which form the home of this bird. The moral is that a scientific excursion to the Chatham Islands is very urgently needed.

Rhipidura flabellifera Gm. Pied Fantail.

This is another of the species which is not only plentiful in the bush districts but has also adapted itself remarkably well to the conditions of settlement. It hawks flies not infrequently in the very rooms of buildings in large towns. At least three factors work in its favour: It is very

difficult of capture by cats; its nest is often absolutely inaccessible to vermin; and a strong popular sentiment has in many places developed, probably in response to its confiding behaviour. We know, however, so very little of the influences of the new conditions on the old in New Zealand that it would be presumptious to suppose that these three advantages afford a complete explanation of the fantail's survival.

Rhipidura fuliginosa Sparr. Black Fantail.

Remaining plentiful and widespread in the South Island, this species still occurs fairly frequently in the North Island. The regular manner in which these North Island records decrease as we go north forcibly suggests that these birds are stragglers from the South Island. The isolation of very closely allied species and subspecies in the two main Islands is a well-known peculiarity of New Zealand ornithology. Records of stragglers in one Island of species peculiar to the other are extremely rare—the writer, in fact, knows none except in this one case, in which, moreover, it is highly significant that the two species are separable at a mere glance. May it not be that stragglers of other species, unless actually shot, are identified *ipso facto* as the species of the Island in which they are seen?

Turnagra tanagra Schlegel. North Island Thrush.

This is practically the only species of which absolutely no records are forthcoming. Its whole history has apparently been one of progressive diminution and disappearance. Elsdon Best (1909) writes, "almost gone from the forests of Tuhoeland." He further states that there are said to be some still in the Parahaki district—a wild uninhabited tract of rough forest country. Four specimens in the Dominion Museum were all obtained on the 8th September, 1900, in a district where the bush to this day is but little touched. The most recent occurrence known to the writer is that of Buller (1905), who records a specimen shot in 1902, and notes that it is the first he has known since 1888. It is of the utmost importance that steps be taken to ascertain whether this truly remarkable species still survives. The meagre information above indicates strongly that the habitat is country of the wildest nature—a fact which may explain the complete absence of any report in Drummond's exhaustive inquiry (1907) regarding the native birds.

Turnagra capensis Sparr. South Island Thrush.

The news of this beautiful species is rather more reassuring than that of its North Island relative. In 1914 and 1921 respectively it was recorded from two South Island localities, one of which is a mountainous region of great extent, in which, as it was plentiful in 1914, it may be able to survive. One observer states that it is very shy. Buller (1905) speaks of it as a fast-expiring species. Fulton (1908) mentions two localities other than those indicated above.

Bowdleria punctata Quoy & Gaim. Fern-bird.

As with so many other species, the diminution in the numbers of the fern-bird is at first sight easily explicable. Wherever its haunts—fern covert or raupo-carex swamps—have been cleared or drained it has very naturally disappeared. There are, however, extensive swamps and fern lands from which it has gone for reasons not easily understood. For

example, Guthrie-Smith (1921) felt that on his run the survival of the fern-bird in undrainable marshlands and boggy creeks was practically assured for all time. In the very next year (1922) he writes, "altogether one" from Tutira. Philpott (1919) had not met with the species in Southland for six or seven years. In Stewart Island, however, he found it plentiful in 1913, while Guthrie-Smith saw it in the same locality (1914). Elsdon Best (1909) records its abundance in the Urewera in bracken and on the edges of swamps. The writer found it abundant in another North Island locality in 1913, but Major R. A. Wilson writes that within the last few years it has disappeared from swamps where it was formerly plentiful in the same district. It is not uncommon in the far North, where it is universally called "matata," and sometimes "swamp-robin."

Bowdleria rufescens Buller. Chatham Islands Fern-bird.

Buller (1895), writing on the authority of his collector, Hawkins, stated that this species had been exterminated by wild cats and by the firing of low vegetation.

Mohoua ochrocephala Gm. Yellowhead.

Philpott (1919) states that "the yellowhead disappeared from the neighbourhood of Invercargill about ten years ago. "He mentions, however, several forested areas in the south-west of Otago where it is still plentiful, and a locality at the northern end of the Island where it is "always to be found" (1922).

Mr. F. G. Gibbs in 1922 saw a large number at a locality in the northern portion of the South Island. The present writer found it not uncommon in a third region. The nest is said to be easily accessible to vermin, but the bird prefers the back country, and will probably survive in the extensive forests of the South Island.

Certhiparus albicilla Lesson. Whitehead.

Like the preceding species, this is essentially a forest-bird. As forests originally covered the greater portion of the North Island it may be presumed that its distribution was primitively much more extensive. In the early days of settlement, however, the numbers of the whitehead began to decrease even in the absolutely untouched forests of the interior. It remained common, nevertheless, on at least one of the islands which have since been declared sanctuaries. As early as 1886 Reischek, a field ornithologist of great energy and experience, considered it extinct or extremely rare on the mainland. Buller (1892) shot a pair in the ranges back of Waikanae, "positively the only ones I have even heard of on the mainland for the last ten years or more." In 1893, and again in 1905, the same writer declared them practically extinct on the mainland. But in the latter year Buller stated that the species was reappearing in a few localities and had changed its habits from frequenting low scrub to resorting only to the highest tree-tops. The species certainly prefers the top of the forest roof now; but the statement that it was ever otherwise requires more evidence. If such a change has taken place, then, as Buller suggests, it will doubtless be an important survival factor. In a large number of widely separated forest areas and wooded ranges the whitehead is now one of the commonest birds, and there is every reason to suppose that it has permanently adapted itself to the new conditions in so far as

they have affected the forest. The writer knows of no case in which it has established itself in settled areas or become in any way independent of the forest; but in forest reserves it should be safe.

Finschia novaeseelandiae Gm. Brown Creeper.

Of this species no startling diminution has been recorded. Fulton (1908) mentioned three localities in which it was fairly plentiful. Philpott (1914) stated that it was still common in Southland, and in 1919 that, "though becoming rather rare in the smaller bush areas, the brown creeper is still common in the larger forests—in one place very abundant." Guthrie-Smith (1914) recorded it from Stewart Island, and Mr. T. Cockcroft and Mr. E. H. Atkinson saw it at two widely separated South Island localities.

Altogether the records at the present day indicate a distribution extending from the north of the South Island to Stewart Island, and an occurrence in such different stations as the manuka thickets of the river-beds and the beech forests of the subalpine regions.

Anthornis melanura Sparr. Bell-bird.

In the whole history of the effect of settlement on the indigenous birds the most extraordinary item probably deals with the alleged extermination in the North Island and subsequent increase of the bell-bird. As early as 1875 Buller wrote, "further inquiries have only tended to confirm my belief that the present scarcity of this and some other species in the North Island is due to the ravages of the introduced rat (*Mus decumanus*), which now swarms throughout the country and will continue probably to increase." Two years later (Buller, 1877) he says, "I may mention, in proof of my former assertion that the korimako, once the commonest bird of the country, is fast becoming extinct, that since my return from England two years ago I have positively not seen one, although I have visited many parts of the North Island." Reischek (1886) stated that it was extinct or extremely rare on the mainland (North Island). Finally, Buller (1893) was convinced that it had "disappeared from the mainland." Meanwhile the bird continued plentiful on the two island sanctuaries, and less so in parts of the South Island.

The first signs of a change came in 1889, when Hamilton said that it had almost disappeared from Hawke's Bay for some years, but was once more appearing in the neighbourhood of Takapau. Elsdon Best (1909) wrote that previous to 1895 it had long disappeared from the Urewera, but in the summer of 1901–2 it commenced to reappear. At the present day practically every report of the bell-bird—and they are too numerous to quote in full—either records its appearance in a locality in which it was hitherto unknown or its increase in older haunts. The following extracts will give some idea of the widespread increase of the bell-bird.

Oliver (1922) says it is "without doubt the most common species of bird" on Little Barrier Island. Major R. A. Wilson writes, "The bell-bird has also considerably increased, and is perhaps the commonest bird in the bush in certain localities"—a middle North Island one, an extreme northern South Island one, and an extreme southern one, with an intermediate station where it has "come back to gardens and plantations . . . where it now breeds freely." Philpott (1919), speaking of south-west Otago, says, "It is gratifying to find that this charming

songster, which at one time was thought to be in danger of extinction, is now one of the most common of the indigenous bush-birds. The smallest patch of forest usually supports one or two individuals, and orchards and gardens in the centre of the town are regularly visited." A correspondent in the *Auckland Weekly News* (19th October, 1922) states that in the neighbourhood of Whakapunaka, near Gisborne, it was never seen nor heard of until one appeared recently. Mr. F. G. Gibbs writes (1922), "The bell-bird is steadily becoming more plentiful, especially on the western ranges." To sum up, the bell-bird is now plentiful in the North Island in widely separated portions of the Auckland, Taranaki, and Wellington Provinces, and occurs in parts of Hawke's Bay; while in the South Island it is distributed from north to south, and on Stewart Island, and is in places not only very plentiful but well adapted to the conditions of settlement. In the North Island, although it occasionally frequents the flowering *Eucalyptus* near the towns, it has as yet shown less tendency to leave the native bush.

Mr. R. S. Sutherland (1922) informs me that the bell-bird is not increasing in one South Island locality; but in two areas, one on each side of this, according to other observers it is very plentiful.

When the bell-bird was disappearing rapidly two main theories were advanced to account for the diminution. The favourite hypothesis (Buller, 1875) placed the guilt on the introduced rats. Travers (1883) even went so far as to suggest that the reason bell-birds were then still plentiful in the South Island was that the wekas there had exterminated the rats. This theory was found more or less inadequate when Buller, in 1895, found bell-birds very common on an islet in Lake Taupo positively swarming with rats—famous, in fact, among the Maori for its super-abundance of these mammals, which had honeycombed the ground with their burrows. The second theory maintained that the honey-supply was lessened to such an extent by introduced bees and by such imported birds as the starling that the indigenous Meliphagine birds were being exterminated. The overflowing honey in any patch of flowering flax or fuchsia; the infrequency with which imported birds are seen sucking the flowers; the abundance of bees in the South Island, where the numbers of the bell-bird have never been so seriously diminished; the abundance throughout the country of the honey-eating white-eye (*Zosterops lateralis* Lath.), the commonest native bird in New Zealand—all these facts proclaim the insufficiency of this theory to explain any of the diminution in the numbers of the native honey-eaters.

Of the subspecies inhabiting the Chatham Islands no recent information is available. In 1905 Buller stated that it was very nearly extinct.

Notiomystis cincta Du Bus. Stitch-bird.

The disappearance of this beautiful species from the mainland at a date so early in the history of colonization remains inexplicable. Of the multifarious theories brought forward to explain the disappearance of various indigenous species, there is not one which may be said peculiarly to fit the stitch-bird's case—to give any inkling of the reason why, of the three endemic honey-eaters, all common on the arrival of Europeans, one should early disappear entirely from the mainland, the second should remain uniformly common throughout, and the third, after practically disappearing, should increase nearly all over both Islands.

That the stitch-bird may be considered safe on the island which forms its sole remaining home is inferred from the following chronological statement: 1885—Reischek stated that it would soon be exterminated on Little Barrier Island owing to the ravages of cats, sparrow-hawks, and moreporks. 1896—T. Kirk drew attention to the large numbers shot on the island by collectors, who have apparently been the greatest curse of this species, though they could hardly have been the cause of its disappearance in the great central forest areas of the North Island. 1912—In the meantime the island had been declared a sanctuary, the Maori inhabitants had been forced to leave, and a caretaker had taken up his residence there. In this year the Rev. Oscar Blundell, during two days in the bush on the island, saw two or three specimens. 1913, 1914—The same observer, on subsequent yearly visits, found it increasing. 1916—Mr. Blundell found it in all parts of the island, and fairly common. 1922—Mr. W. R. B. Oliver stated it was always to be seen in certain localities.

Mr. H. Guthrie-Smith writes, "The stitch-bird is quite safe, given fair play, in Little Barrier."

Prosthemadera novaeseelandiae Gm. Tui.

The tui is holding his own as the commonest endemic honey-eater in the North Island, and is even in some localities increasing slightly (Mr. R. H. D. Stidolph, 1922). In some parts of the South Island which would seem in all respects suitable it has disappeared, while in others it is less common than the bell-bird. Taking into consideration, however, the whole of New Zealand, its distribution is remarkably wide—from North Auckland to Stewart Island. In some localities, moreover, this beautiful bird has adapted itself more or less to settlement conditions, feeding abundantly on the flowers of *Eucalyptus globulus,* and even in one case nesting in a pine plantation (Mr. R. H. D. Stidolph, 1922), and in another in introduced trees in a garden (Mr. W. E. Atkinson, 1922). Guthrie-Smith (1921) considers that the tui will always survive in the gorges on his Hawke's Bay run. Philpott (1919) writes, "The tui is not uncommon in the large forest areas, but appears to favour the lowland mixed type; not many are to be met with in the *Nothofagus* mountain blocks."

The tui is one of the few indigenous species concerning which there has been brought forward definite evidence as to the direct effect of introduced birds. Thomson (1922, p. 147) writes, "Mr. L. J. Phillips, of Kaitoke, states that on several occasions he has seen two or three blackbirds set on and kill a tui." In view of the well-known pugnacity of the tui, so often successfully displayed against, for example, long-tailed cuckoos and kingfishers, this appears so extraordinary that confirmation by several observers would be welcome. With regard to the starling—a species which, by its appropriation of nesting-holes, coupled with its wide distribution, has probably done more than any other imported bird towards the displacement of the native birds — a correspondent from Coromandel writes in the *Auckland Weekly News* (9th November, 1922), as follows: "A tui had perched on the edge of a hollow broken limb of a kauri where a starling had a nest. The tui sang uninterruptedly until the starling came along to see to its nest. It perched a few feet from the tui, stretched out its neck, and screamed and screeched. The tui seemed too startled to move. It stayed there, but only for a few seconds, as some dozens of starlings that had settled in the tree swooped down on it.

The tui did all it could to get away from them, but it was too late, and they beat it to the ground. For a minute it was nothing but a rolling, screaming mass of birds on the grass. The tui lost many feathers, but finally got away."

Austranthus novaeseelandiae Gm. Ground-lark; Pipit.

This engaging little bird is so well adapted to open country and native tussock associations that with the spread of pastoral areas it is more than maintaining its numbers. In Hawke's Bay, Guthrie-Smith (1921) includes it among the species which have actually gained by the progress of settlement, and there can be little doubt that this is true of New Zealand as a whole. Even roads are a favourite haunt in some districts. Speaking of south-west Otago, Philpott (1919) writes, "Not uncommon in the open country round Invercargill. It is strange that this bird, which nests and roosts on the ground, does not succumb to the stoat in a district where these animals are so plentiful." It is difficult to say whether any actual competition even in regard to food-supply exists between the ground-lark and the introduced skylark. On cultivated ground doubtless the latter will always remain the commoner; it has even established itself on some of the dune areas and on the alpine tussock slopes on the Tararua Range; but on the vast area of the mountain tussocks generally, on the sea-coast (whether sandy or rocky), and on second-class sheep-country the ground-lark should easily maintain itself.

Heteralocha acutirostis Gould. Huia.

So far as the writer is able to ascertain, the last specimens of this famous and anomalous species actually seen by an ornithologist were two males and a female observed by Mr. W. W. Smith on the 28th December, 1907. The evidence for its continued existence in the mountain fastnesses which form its original home is practically as good as that on which the kea is convicted of sheep-killing — namely, the witness of non-scientific observers. Of such reports of eye-witnesses within the last six or seven years the writer, chiefly through the help of Mr. R. H. Stidolph, has been able to collect seven, the most recent of which was as late as August, 1922. While several excursions have been made to likely localities, no examination has yet been made of the area which the writer considers most favourable.

There can be no doubt whatever that the chief guilt for the diminution in numbers of this magnificent bird must be laid on the shoulders of collectors—firstly of Maori with native weapons, doing little harm and penetrating but a short distance into the mountain retreats; secondly of Maori armed with shot-gun and incited by the money of pakeha collectors—this was the beginning of a veritable massacre, of which the survivors were shot or driven back by the collectors themselves. The increase of settlement can have been but a small factor in the decrease of the huia in the historic period—even to this day a large part of its known habitat from time immemorial remains almost intact and is secured by forestry, water, and scenic reservation from further interference.

G. E. Mason (1921) records the discovery of five ticks on the under-side of one of the wattles in a skin (female) formerly in the collection of Buller shot twenty miles from Masterton in 1883. The ticks belonged to two species, *Haemaphysalis leachi* Aud. and *Hyalomma aegyptium* (Linn.), both

of widespread but chiefly Oriental and African distribution, and neither previously recorded from New Zealand. Mason states that both species have occurred on the mina (*Acridotheres tristis* L.) in its native home; and, as this bird was introduced into New Zealand in 1875 and speedily became established, it is possible that the huia received its parasites from this source. Mason further remarks, in support of this theory, that Taylor White observed conflicts between huia and mina during which opportunity for infection may have occurred. Ticks are well-known disease-carriers; in fact, one of the species concerned here transmits dog-distemper. It is therefore quite possible that an avian disease was thus transmitted to the huia.

Creadion carunculatus Gm. Saddleback.

The disappearance of the saddleback occurred so early in the history of the colony that it is very difficult to explain in terms of any known introduced factors. According to Mr. Stidolph (1922) Mr. P. J. O'Regan observed that it died out in Westland before the introduction of stoats and weasels. This must also have been the case with the mainland of the North Island, where its numbers early diminished. On Tutira (Guthrie-Smith, 1921) it disappeared before settlement began. In 1905 Buller wrote that the species had entirely disappeared from the mainland. Either Buller was misinformed or else the species has recolonized the main islands and increased slightly in numbers, for there are now records from an extensive mountain region in the South Island in 1914, from another in 1916 and 1922, and from an inland North Island locality in 1921 (Mr. A. H. Messenger). In addition it is very plentiful (1922) on an islet off the coast of the North Island, where it was rediscovered by Mr. W. M. Fraser. This latter locality is so small and the birds so numerous that it should be the aim of every bird-lover in New Zealand to see that efficient protection be accorded against predaceous animals, and, above all, against collectors. Another South Island locality, other than those mentioned above, is known, making five altogether.

Callaeas cinerea Gm. Orange-wattled Crow.

With the spread of settlement the diminution of the numbers of this tame species was almost inevitable. Even as early as 1889 W. W. Smith spoke of its "rapidly approaching extinction." He considered dogs and cats its greatest enemies—an honour reserved by Fulton (1908) for collectors. Two localities for the South Island crow have recently been recorded on the mainland—one an extensive mountainous area where it should have every chance of survival. On Stewart Island it is still plentiful in certain areas (Philpott, 1914).

Callaeas wilsoni Bonaparte. Blue-wattled Crow.

This beautiful species supplies one of the greatest surprises of the investigation. Originally widely distributed and not uncommon, by 1887 it was already sufficiently diminished in numbers to make a disappearance theory necessary. (Reischek, 1887.) Guthrie-Smith (1909) included it among those species which disappeared from Tutira, Hawke's Bay, before settlement began there. Elsdon Best (1909, 1910) wrote that it was very scarce in the Urewera, but lately reappearing. It is now reported from ten localities in the North Island—mostly situated in the northern or middle portion. This year (1922) the writer, to his intense

astonishment, was shown a small piece of mixed lowland bush, fortunately a reserve, on which these beautiful birds are quite plentiful, although it is situated only three miles from a populous town in the midst of pastoral country. This seems to indicate that if specimens of the crow can be placed on other reserves, and well protected from collectors, who are undoubtedly the greatest enemy, they may increase or at least survive. Mr. T. Cockcroft has lately found another isolated patch of bush inhabited by several birds of this species.

Buller (1905) wrote, just a short time before his death, "There is just the chance that in the course of time some of these vanishing species may learn to adapt themselves to the new condition of things and take a fresh lease of life." We are witnessing the fulfilment of this prediction, and the measure of the fulfilment will be the measure of our care in giving the indigenous avifauna every possible chance to reassert itself.

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ELECTRICITY IN DAIRY FACTORIES.*

By C. VOWELL, Assoc.A.I.E.E., Grad.I.E.E., London.

THE value of electricity to mankind lies in the three main effects it is capable of producing—namely, (1) magnetic effect, (2) heating effect, (3) chemical effect.

The first, which is always present when any electric current flows, is the most important of all. Upon it depends the working of all electric bells, telephones, telegraphs, electric motors, and electro-magnetic apparatus. Electric motors alone now supply many millions of horse-power. The magnetic effect produced by an electric current is directly proportional to the current producing it, or, in other words, if the current is doubled, the magnetic effect is also doubled.

The heating effect, which is second in importance, is also always present whenever an electric current flows, and is also directly proportional to the current producing it. Upon the heating effect depends all electric lighting, heating, cooking, &c., as well as the operation of the electric furnaces used for making calcium carbide, carborundum, and nitrogenous compounds for use in manures and explosives, &c.

Chemical effect: Under suitable conditions an electric current will also produce a chemical effect, which, like the others, is also directly proportional in amount to the current flowing.

In dairy factories the chief uses to which electricity may be applied are the driving of the machinery by electric motors, and the heating of water and milk. Before discussing the various methods of driving dairy-factory machinery by electricity it will be helpful to define the main electrical terms.

The electrical unit of pressure, which is analogous to pounds of pressure per square inch in steam, is the volt. One volt of electrical pressure is a little less than the pressure that would be obtainable from a single-cell battery such as is used for ringing electric bells. The unit of current is the ampere, and is analogous to the volume of steam passing through a steam-pipe. The power supplied to a steam-engine depends upon the pressure of steam in the steam-pipe and the volume of steam passing through the steam-pipe. Exactly the same is the case with electricity: the power supplied to an electric motor depends upon the current and the pressure of voltage at which that current is supplied.

For power the unit is the volt-ampere or watt; the power in watts being the product of volts and amperes. As the volt-ampere or watt is a very small amount of electric power, a larger unit is used, known as the kilowatt, which is 1,000 watts. It will be interesting at this stage to note that 746 watts, or about three-quarters of a kilowatt, are equal to 1 horse-power.

With steam working the amount of energy supplied by a steam-engine is measured in horse-power-hours—or, in other words, the horse-power developed by the engine multiplied by the number of hours it has been working. Similarly, with electric power the amount of energy supplied

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* A paper read before the Southland Dairy-factory Managers' Association at Wyndham on 1st March, 1923.

is measured in kilowatt-hours, or the number of kilowatts being supplied multiplied by the number of hours' duration of the supply. The kilowatt-hour is commonly known as the Board of Trade unit, and is spoken of merely as the unit of electricity.

The Southland Electric Power Board rates for electric energy are as follows :—

	Per Unit per Month.
For the first 21 units	7d.
For the second 21 units	4d.
For the following 42 units	2½d.
For all over 84 units	1½d.

It will be seen from this sliding scale of charges that the more electric energy consumed the lower will be the average price per unit. Take, for example, a consumer using 100 units per month : his bill will come to £1 10s., or an average of 3·6d. per unit. If he consumes 200 units per month his bill will be £2 2s. 6d., or an average of 2·55d. per unit ; and if he consumes 300 units per month his bill will come to £2 15s., or an average of 2·2d. per unit. It is therefore apparent that the greater the use made of electricity the lower will be the cost per unit or per horse-power-hour.

In tests on the driving of separators by electricity and steam which were carried out recently the following methods were employed. The results are valuable, and they go to prove that dairy factories in Southland cannot afford to use steam where electricity is available at the above rates.

In the steam test half a ton of coal was carefully weighed out and reserved for use during the separating-period. The fire was worked into good condition, and 100 lb. of steam raised on the boiler. This head of steam was maintained approximately constant both before and during the separating-period. As soon as the separators were started the boiler was fired from the half-ton of coal specially reserved. At the end of the separating it was calculated that nearly a quarter of a ton of coal remained. The cost of the coal (Kaitangata) delivered into the bunker is £1 11s. per ton, and the quantity of whey separated was 3,000 gallons. Thus the coal-cost of separating 1,000 gallons of whey by steam-power works out at slightly over 2s. 7d., or 3·1d. per 100 gallons. It must be noted that the fire and boiler were left at the end of the test in the same condition as at the beginning —that is, with a full head of steam. The quantity of coal burnt in raising steam has not been added in ; if it were the cost of separating by steam-power would be still higher.

In the electric test the A.V. 6 Alfa-Laval separator was driven by an electric motor by means of Vowell's constant-tension drive. A house-service type of kilowatt-hour meter was installed to measure the quantity of electric energy consumed. The separator was run up to speed for a consumption of 0·88 unit. The speeding-up occupied 28½ minutes, the constant-tension apparatus being set for a slow acceleration.

Separating was commenced and continued for one hour, during which time approximately 600 gallons of whey were separated for a consumption of 2·59 units, or a total consumption from the commencement of speeding-up of 3·47 units. Had separating been continued for a longer period the proportion of the energy consumed in speeding-up to that used in separating would have been less. If we neglect the energy consumed in speeding-up, the consumption of electricity per 100 gallons of whey separated works out at 0·431 unit, or, including the energy consumed in speeding-up, 0·578 unit.

In a second test 200 gallons of whey were pumped into the separator-vat, and it was found that the time occupied in separating this quantity was 18 minutes, and the consumption of electricity 0·72 unit, or 0·36 unit per 100 gallons. This does not include energy used in speeding-up.

In a third test two separators were driven by steam and one by electricity. It is assumed that the one driven electrically separated one-third of the day's total quantity of whey, which was 2,850 gallons. The total consumption of electricity, including speeding-up, was 5·08 units, or 0·53 unit per 100 gallons of whey separated. From the foregoing test the average consumption of electricity for 100 gallons of whey separated, including speeding-up, works out at 0·554 unit. Taking the last seasons whey at 722,188 gallons, the consumption of electricity for separating during the nine and a half months that the factory was open would have been 4,000 units, which would have cost £33 15s. The consumption of coal chargeable to separating for that period was not less than 60·18 tons, costing £93 5s. 6d. The saving in favour of electricity is thus £59 10s. 6d., or 63·8 per cent.

ADDENDA.

On the 30th May, towards the close of the season when the supply of milk had reduced sufficiently to allow all the whey to be skimmed by one separator, the following results were obtained in a steam test using Mataura lignite (which is delivered into the bunker for 14s. 9d. per ton) for fuel.

Whey separated, 793 gallons; fuel consumed, 3½ cwt., cost 2s. 7d. Cost per 100 gallons of whey separated, 3·9d.

In an electric test made on the 2nd June, when all the whey was skimmed by the same single separator but driven by electricity, the following results were obtained: Whey separated, 922 gallons; electricity consumed, 4·38 units; cost (estimated on probable season's consumption), 8·88d. Consumption per 100 gallons of whey separated, 0·475 unit. Estimated cost per 100 gallons of whey separated, 1d.

It will be seen that the consumption of electricity in this test is 0·079 unit per 100 gallons of whey separated less than in the previous tests. This is probably due to better adjustment of the driving-apparatus. It will also be seen that the cost of separating by steam was 0·8d. higher per 100 gallons of whey separated than in the previous test. This is due to the inherent inefficiency of collective driving, which becomes more apparent when a factory is working at part capacity. In this case only one out of three separators was in operation. The higher cost also suggests that although the fuel being used was less than half the price of that used in the earlier test the increased amount required renders it less economical.

It must be remembered that this is the saving in the fuel bill alone, if only the separators were driven electrically. If the rest of the machinery were driven electrically the percentage of saving would be even greater, owing to the gradually reducing price per unit charged for electricity. Other economies would be effected, such as reduced maintenance of boiler and engine, reduced renewals of belts, reduced consumption of oil, saving of labour in boiler and engine attendance, &c. The very considerable economy effected by the use of electricity is due in no small measure to the efficiency of the constant-tension drive, which has the unique function of maintaining a perfectly uniform turning effort on the pulley of the separator. Even the slight variations which would be produced by sticky or greasy patches on the belt are compensated for.

This brings out an important point in the electrification of dairy factories. Had a large motor been installed in the engine-room little or no saving would have been effected. A little consideration will make this clear. The electricity used at Wyndham is generated in Invercargill by steam-power and then transmitted a distance of twenty-seven miles. If the steam-engine is merely replaced by an electric motor of equal power its operation at Wyndham would necessitate the consumption of an amount of coal at Invercargill power-station nearly equal to that required by the present steam-engine, the only economy it would be possible to effect being due to the higher efficiency of the steam plant at Invercargill power-station as compared to the efficiency of the small steam-engine and boiler at the factory.

It is only by careful and scientific installation of motors of the correct power and specially designed for the particular machine they are to drive that the maximum economy may be obtained. Collective driving by electricity—that is, driving the whole factory by one large motor—is comparatively inefficient, although it still has to be used in the case of steam-power. Individual drive—that is, one motor for each machine or group drive, in which case two or more similar machines are grouped together and driven by one motor—is the more efficient method of applying electric motor drive. Each method has its advantages and disadvantages, and these have to be carefully considered with relation to the cost of installation of each method.

Individual drive has the advantage of allowing of direct coupling to the driven machine, or where belting is necessary it is reduced to a minimum: this reduces maintenance and running-costs in belt-renewals and oil. A further advantage is that a motor of the exact power required to drive the machine may be used. It also enables the motor to operate at higher efficiency, for the reason that electric motors, in common with other prime movers, operate most efficiently at or near their full load. Another advantage of individual drive is that the driven machines, together with their motors, may be made self-contained units. This is of great advantage where there is a possibility of the plant having to be moved or reduced in size, or where part only of the plant is required at the beginning or towards the end of the season.

One disadvantage of individual drive is that the capital cost of several small motors is greater than that of a few of larger size, giving the same total horse-power. Another disadvantage becomes of importance when the machines to be driven require only little power. This is due to the fact that small electric motors have an inherent lower efficiency than large ones. It is on account of these two disadvantages that the group method is used. To obtain the maximum economy with group drive, only similar machines, or machines with similar operating characteristics, should be grouped together. Of these machines only those which start up and shut down at the same time should be included in one group.

The chief advantage of group drive is that fewer motors are required, which reduces capital cost; also, the motors used are larger, and therefore more efficient. Machines which occupy a large floor-space relative to the power required by them should not be grouped, as the loss of power in belts and shafting more than offsets the increased efficiency of the motor; also, the capital cost of the belts, shafting, plummer-blocks, &c., more than offsets the reduced price per horse-power of the larger-sized motors.

Electricity for heating purposes in dairy factories does not show up to the same advantage as for power. In fact, in Southland, with its abundance of lignite easily mined, electricity for heating purposes on a large scale cannot compete. The reason is that £1 worth of coal contains vastly more heat-units than £1 worth of electricity. Small-size electrical-heating apparatus, such as electric kettles, are now made with the very high efficiency of 80 to 90 per cent., which enables electricity to compete favourably with such inefficient appliances as a cast-iron kettle heated on an ordinary fire. When, however, the more efficient system of heating by high-pressure steam is used, generated by an efficient steam boiler, the cost of heating by steam is considerably lower than by electricity. It must be remembered, however, that for heating small quantities of liquid electricity is probably the next cheapest source of energy, and also possesses the great advantage of being ready for use at any time of day or night, and may be automatically regulated.

At the present time the tendency in pasteurizing is to increase the speed with which the temperature of the milk is raised and lowered. Electricity would be capable of giving a higher temperature surface than steam, and therefore could be used more efficiently than steam in a flash pasteurizer. Another use of electricity in pasteurizing or sterilizing is at present being experimented with. It consists of exposing the milk to the action of the ultra-violet rays emitted by the mercury vapour electric lamps. These rays are chemically active and produce an effect similar to sunburn if allowed to impinge upon the skin. Sunlight is one of the best sterilizing agents, and this artificial sunlight has a similar effect.

In conclusion, I suggest that the great advantages which may be derived by using electricity to operate dairy factories behoves all dairy companies within the electrically reticulated area to give earnest consideration to the electrification of their factories. There are thus great possibilities of future development in the application of electricity in dairying.

LEVEL CROSSINGS.*

By G. W. WYLES, A.M.I.E.E.

THE subject of level crossings and the prevention of accidents is of considerable importance at the present time in several countries, particularly in New Zealand, Australia, South Africa, and America. It is a problem which has occupied the attention of most people concerned with transportation for some considerable time, and, owing to the fact that part of the question involves dealing with the personal equation of a large proportion of the population of the country, it is one for which it is difficult to find a solution. Many diverse opinions have been expressed in regard to the matter, and from my own experience I should say it has been one of the most popular problems for inventors. I propose to deal with the subject by first pointing out the general considerations, then describing some methods of protection in use, and finally giving some of the results of the provision of protection.

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* A paper read before the Technological Section of the Wellington Philosophical Society, 16th May, 1923.

I. At level crossings the position is that two conflicting streams of traffic, both moving at high speeds, intersect, and the consequent liability to accident is the result. So long as one stream of traffic was slow, accidents were few and far between; but during the last few years they have become a frequent occurrence, due to the growth of motor traffic and the consequent increase of speed.

Railway traffic must maintain its speed, and no reduction of its speed over crossings is possible. In other words, the railway traffic must have right of road over the more mobile road traffic. All the warning that can be given, apart from signals, is for the engine to whistle on approaching a crossing and give warning of its approach. This is the universal practice.

From the contention that reduction in the speed of railway traffic is not practically possible it follows that the road traffic must comply with certain restrictions to ensure immunity from accident. Now, provided that speed-control is carried out and road vehicles approach crossings at low speed, the liability to accident will be reduced to a very large extent; and I justify this statement by the records of very infrequent accidents in the past before the road traffic was motor-driven. The increase in railway traffic also affects the question somewhat; but, personally, I am convinced that the slower the speed of road traffic over a crossing the fewer will be the accidents. The problem to me, therefore, appears to be, How is speed-reduction to be enforced?

The necessity for this reduction involves the provision of indication to road traffic that it is approaching a road-crossing. This has been provided for by the installation of signs by the roadside, one generally some distance from the crossing and one at the crossing itself; and in the large majority of cases these signs would be sufficient to guard against accidents if their indication to "Stop, look, listen," were obeyed and proper caution exercised. The experience was, however, that accidents continued to occur, largely through road traffic not acting upon the warning conveyed by the signs, and demands were in consequence made for the provision of signals to indicate when trains were approaching the crossing.

The real cause of the demand was, first, that some accidents occurred through road traffic not taking notice of the roadside notices and not exercising sufficient care, and these accidents were then used as an argument for the provision of warning-signals which would indicate when a train was approaching, and thus provide further warning for people who did not comply with the road signs.

One of the consequences of the installation of warning-signals, which may or may not have been foreseen, was that, although they give an actual warning of a train's approach, they also created a tendency to ignore the road signs, and the "Stop, look, listen" caution became as a result more honoured in the breach than the observance, and probably caused a general increase in speed. This increase in speed greatly aggravated the liability to accident, even with the most efficient warning-signals; while a failure of one under these conditions brings about a condition of very real danger. The result of speeding-up on some crossings has a tendency to increase speed generally at all crossings, with the resulting increase of liability to accident generally.

Some investigations recently made in regard to the caution exhibited by people using a crossing showed some almost unbelievable results. A test made in a large town for a period of forty-eight hours showed 1,286 pedestrians used the crossing and 2,931 motors. Only 3 per cent. of the

pedestrians looked in both directions, 9 per cent. looked in one direction, and 88 per cent. neither stopped nor looked either way; and 91 per cent. of the motorists neither stopped nor looked in either direction.

When accidents occur they nearly always result in damage to road traffic, and are frequently attended with fatal consequences. This is bad enough; but there is in addition always a liability that a train may be derailed, particularly when heavy motors are involved. The possible consequences of a train being derailed at high speed under these conditions are anything but pleasant to contemplate. For example: A collision occurred on the 21st August, 1922, between a passenger-train and motor-lorry at Annadale, in America. In this case the driver of the lorry was driving at from twelve to fifteen miles per hour, and was signalled to stop by a brakesman, the motor being about 225 yards away when first signalled. The driver and a companion were talking and took no notice. At 50 yards distance he saw the approaching train, and was seen by the passenger-train, which was travelling at fifty miles per hour. The lorry was struck and hurled against the points, damaging them and causing a derailment. In spite of the train being equipped with the emergency brake, which was applied, the result of the accident was eight people on the train killed, thirty-five injured, together with the two occupants of the motor.

Unfortunately, the gross carelessness, coupled with failure to take any precautions, displayed in this case, when approaching a crossing, is by no means uncommon, as shown by the records of numerous accidents, although generally the consequences are confined to the people responsible for the accidents. There is, however, another aspect in regard to these accidents, and that is the effect on the engine-driver; and it will be obvious that an engine-driver who has been in collisions at level crossings may lose some of his nerve, and consequently not be as ready to deal with emergencies.

II. *Protection of Crossings.*—The various means adopted for the protection of crossings are—

(1.) The road signs.
(2.) The warning-signal—audible, visual, or audible and visual.
(3.) The crossing-keeper.
(4.) Gates or barriers, worked either by hand or machinery.
(5.) Road-humps.
(6.) Road barriers or circuitous routes on to the crossing.
(7.) The elimination of the crossing by an overbridge or subway.

The first method I have already dealt with; and if the road signs were obeyed they would in nearly all cases result in immunity from accidents; but, as it is practically impossible to check compliance with regard to slowing down, they provide protection for the careful driver only.

The warning-signal: This signal I have also mentioned previously in regard to its possible effect of increasing speed generally, although conveying an efficient warning. These warning-signals are operated automatically on the approach of trains, in many cases the warning consisting of a loud ringing bell. The signals are effective in regard to their operation, and if listened for and obeyed provide a very effective warning.

Another type of signal consists of the visual signal. This is operated automatically in a similar manner to the bells. It may consist of a moving disk containing a moving light at night, or a flashing colour signal (green for "Clear" and red for "Danger"), or, again, in some cases a steady colour signal may be given.

The first type is a very suitable signal, and when of good design attracts the attention when moving on the approach of a train. The colour-light signal, both flashing and steady, does not move its position to give the indication as does a swinging banner or light, and therefore it depends on the change of colour to give the indication. Now, a large number of people are colour-blind, many being unaware of the fact, and the signal in consequence is not, in my opinion, so effective as those of other design, although a number have been installed.

The last type of signal is both visual and audible, and consists of a swinging banner, and light at night, combined with a loud ringing bell, and up to the present appears to be the best combination for attracting the attention; and a number of this type have recently been installed in New Zealand. There is no doubt that this signal caters for practically every one, being both visual and audible.

All of these signals involve the installation of track circuits, and are comparatively costly to install and maintain. Generally they are very efficient in regard to operation as now installed, and failures are few and far between, and when they do occur are generally due to tampering, the large percentage of failures being due to broken bond wires. There are some situations, however, where it is not practicable to install these types of automatic signals, as I will explain later.

The crossing-keeper: This gentleman should generally be quite an effective means of protecting a crossing in most respects, provided, of course, his signals are obeyed; but from the point of view of finance the cost of staffing of all crossings would be prohibitive. This will be obvious when it is remembered that many crossings would require to be staffed for sixteen hours or longer daily. I need not enlarge on the question, as it will be apparent to you that it would be a hopelessly impracticable proposition to staff many crossings in this way.

Some recent commissions in America have, however, laid it down that it is better to have an efficient automatic warning-signal and eliminate the human element. In one recent case mechanically worked gates with a crossing-keeper were removed, in spite of protests, and warning-signals were installed, with apparently satisfactory results. (I might mention here that only a few weeks ago a case occurred where two motor-drivers, ignoring the crossing-keeper, did their best to kill a member of the Railway service.)

Gates: Gates are provided almost universally in England and India. The gates are worked by a crossing-keeper in the latter country, but frequently from the signal-box in England. In England level crossings, however, may be said to be few, comparatively speaking, and the road traffic is, or was, very well disciplined, with the result that mechanically worked gates were quite satisfactory. On the other hand, in India mechanically worked gates coming within my knowledge were not satisfactory, as they proved themselves another danger by either trapping the public on the railway or catching them when being operated; and I understand that in America and South Africa the same disadvantages have been found.

Gates are in many cases only practicable when in close proximity to a cabin, and the first cost and maintenance is very high; also it would be necessary to install warning-devices to indicate when the gates are to be operated.

The attended gates cannot be considered, for the same reasons as those given for crossing-keepers.

Road-humps: This method of procuring a reduction of speed by forming corrugations in the road has been suggested and, I believe, tried. It is not a popular solution, though it would probably be most effective in securing a reduction in speed. These are certainly not pleasant to drive over at speed, but properly designed do not cause any trouble, and the matter resolves itself into a question of proper consideration for general public safety.

Road barriers or circuitous approaches: These are some very recent suggestions, and I am inclined to think may prove an efficient method of controlling the road traffic and preventing accidents. The idea consists of the provision of an approach to the crossing which compels a sharp turn to be made, compelling a reduction in speed, and may be worthy of serious consideration. Such an arrangement would provide all the protection required for the large majority of crossings, and, combined with, possibly, an automatic signal at completely blind crossings, may prove a satisfactory scheme. There is, of course, still a danger of collision between motors themselves if the speed is high and the rule of the road is disregarded.

I specially mention the completely blind crossing, as many crossings which are considered bad are dangerous only when speed is not reduced; but there are some crossings on curves where some form of warning-signal is necessary. But here again the question arises as to whether motorists are to display a disregard of public safety.

Lastly, the bridge: In populous districts where both railway and road traffic is heavy the bridge or subway is the only final solution from the safety-point, and this applies particularly to crossings in or adjacent to station-yards; but here again the question of finance enters largely, as also the question of by whom the cost of conversion is to be borne.

Warning-devices have been installed in such cases, but they are unsatisfactory, and frequently very costly, and are only a temporary expedient at best. In many of these cases the bridge is the only solution.

I would like here to quote from Mr. F. W. MacLean's presidential address to the Society of New Zealand Engineers. Speaking in regard to the cost of warnings, he says: "When the first cost and the capitalized cost of maintenance and operation (especially where attendants are necessary) are considered, these costs appear to be out of all proportion to the amount of security obtained, and frequently would go a considerable way to defray the cost of a bridge, which, after all, is the only satisfactory solution to the problem." This opinion, I may say, is fully endorsed in other countries.

The problem generally is not confined to New Zealand. In the Administration reports from South Africa, Canada, and the United States the level-crossing question and the regrettable loss of life due to accidents is referred to at considerable length.

In regard to protective devices, New Zealand is by no means behind; but the consensus of opinion expressed in all these reports is that accidents would not occur if proper care was taken by the user of the road, and that warning signs and signals will not deter the people who take risks or who are careless.

In regard to the efficiency of warning-signals the following is an extract from the American Interstate Commerce Commission for 1920 (*Railway Signal Engineer*, July, 1922, page 254):—

"1,083 occupants of automobiles were killed and 3,000 injured in grade-crossing accidents in 1917, as compared with 1,273 killed and 3,977

injured in 1920. Of the 1,201 occupants of automobiles killed in accidents in which the automobile was struck by the train, 931 deaths happened at crossings protected by flagmen, 154 at crossings where audible signals were in service, 22 where audible and visible signals were used, and 24 at crossings where visible signals only were employed. It is astonishing to note that during 1920 there were 404 accidents in which the automobiles were driven into the side of the trains. Of the 71 persons killed in these accidents, 2 were the result of driving through closed gates, 5 from not obeying the flagman, 9 deaths were caused at crossings protected by audible signals, while 52 deaths occurred at unprotected crossings. It may be pertinent to point out here that no deaths resulted from automobiles running into the sides of trains where audible and visible signals were installed. From this it will be noted that the totals for 1920 (1,273 killed, 3,977 injured) are considerably greater than in 1917 (1,083 killed and 3,000 injured), in spite of the fact that from 1917 to 1920 the installation of warning-signals was being pushed ahead.

"Of these accidents in 1920, 1,201 were due to the motors being hit by trains; of these, 1,131 were at crossings protected in some way. There were 404 accidents due to driving into the side of the trains.

"In 1921, 148 accidents occurred at crossings protected by gates, 285 at crossings protected by keepers; crossings protected by audible and visible signals had 48 accidents, 333 accidents at crossings with audible signals, and 30 at crossings with visual signals; 509 accidents were caused by motors running into the side of trains, 363 at unprotected crossings, and 146 at those with some form of protection.

"The distribution of accidents at level crossings from 1917 to 1921 is as follows:—

	1917. Per Cent.	1918. Per Cent.	1919. Per Cent.	1920. Per Cent.	1921. Per Cent.
Pedestrians	18	16	14	10	9
Occupants of motors	59	63	73	76	80
Occupants of other vehicles ..	23	21	13	14	11
	No.	No.	No.	No.	No.
Total casualties—Killed and injured	6,733	6,535	6,400	6,868	6,573
Automobile occupants	4,083	4,240	4,790	5,250	5,287"

A description of an actual installation of warning-signals may be of interest. I will describe a single-line crossing, and it presents some special features which do not exist on a double line, inasmuch as trains approaching from either direction must on the single line operate the warning, which must cease when the train leaves the crossing.

First a track-circuit has to be installed of suitable length to give sufficient warning. The length varies according to grade and local conditions: it is as important that the warning should not be too long as it is that it should be long enough. In practice, tracks are from 400 to 800 yards. The track-circuits are installed on both sides of the crossing and meet at the crossing. The track-batteries are installed at the far ends of the track-circuits. At the crossing is provided an interlocking relay fitted with requisite contacts. The relay is a double one, or, rather, two single ones in one case with an interlocking-device between them.

Normally the power from the batteries passes down the rails through the relay coils and back by the other rail to the battery, and the relays are consequently energized. De-energized contacts on the relay are connected to the warning-signal with a local battery for operation. As soon

as the train enters on to the track-circuit the battery is short-circuited and the one relay drops, making the contacts, and the signal commences to operate, and continues to do so until the train reaches the crossing. As soon as the train reaches the second track-circuit the other relay drops and engages in the interlocking-device, and does not drop on to the contacts. Then, as the train leaves the first track the relay picks up and breaks contact, and although the second track is de-energized the relay cannot make contact, as it rests on the interlock.

Load cells of 500-amp.-hour capacity are used for the track, two cells in parallel being connected up to the track, voltage being 0·5 volt. The local battery consists of Gordon, Burnham, or Leclanche cells, from 10 to 15 volts being used, and generally two batteries are paralleled to be on the safe side. All the wires on recent installations are carried in wooden trunking.

Following on the description, the difficulty of installing warnings at crossings in station-yards will be appreciated. Where the yards are in close proximity to the crossing it is continually occupied, causing an almost continuous operation of the warning-signals by trains in the vicinity, many of which may never reach the crossing. The almost continuous operation soon causes the signal to be disregarded, and it ceases to afford any protection.

Finally, it would appear that nothing except the bridge will afford absolute safety; and, further, that the greatest protection against accidents is the carefulness of the drivers of road vehicles themselves. Warning-signals may help in the case of careful drivers, and are useful at blind crossings, but, unless combined with a careful lookout, will not prevent accidents. Gates and crossing-keepers are, from experience, less efficient than the warning-signals.

The liability to accident increases with the speed, and therefore the question of humps or circuitous routes to the crossing, forcing a reduction in speed, needs very careful consideration. Public opinion and publicity generally has also been found to be a very useful factor in impressing the necessity for a careful lookout to be kept.

In Belgium, after the war, crossing-keepers were abolished at a large number of level crossings. The economy resulted in a saving of three and a half million francs per annum. Special warning-posts were erected, and the civil authorities asked to warn people to take care. There were a certain number of complaints, but scarcely any accidents resulted. The practice is now well established, and the public have become educated to the arrangement. Busy crossings are, however, still guarded.

In Roumania a considerable number of crossings are not guarded at all, but it is found that nearly all accidents occur at guarded crossings, the reason given being that drivers, knowing a crossing to be guarded, cross it without troubling to look.

In France negotiations are under way to dispense with crossing-keepers and leave crossings unguarded. Warning-signals are not being considered, on account of the cost.

In Italy there were seventeen thousand crossings and seventeen thousand crossing-keepers. In consequence of the eight-hour day the staff had to be increased by nearly one-third; and, as the expense cannot be faced, legislation is being prepared to allow level crossings which are not concealed to be unguarded. Road signs are to be erected at unguarded crossings, and the provision of warning-signals at some crossings is being considered.

THE ECONOMIC VALUE OF "WHALE-FEED."

Research by G. STUART THOMSON, B.Sc., and GEO. M. THOMSON, F.L.S., F.N.Z.Inst.

EVERY summer large shoals of a bright-red shrimp are met with in the sea round the coast of New Zealand. This animal, popularly known as "whale-feed," is a swimming stage in the life-history of a crustacean technically known as *Munida gregaria*. It belongs to the family Galatheidae and the suborder Anomura, and is therefore allied to the porcelain-crabs and hermit-crabs of the New Zealand coast. The species is not confined to New Zealand, but is widely distributed throughout the temperate seas of the Southern Hemisphere. Most of the early voyagers, such as Dampier and Cook, met with it on the Brazilian coast. Darwin, in the *Voyage of the "Beagle,"* reported it from the sea round Tierra del Fuego, where, he says, "I have seen narrow lines of water of a bright-red colour, from the number of Crustacea, which somewhat resemble large prawns. The sealers call them 'whale-feed.' Whether whales feed on them I do not know, but terns, cormorants, and immense herds of great unwieldy seals derive, on some parts of the coast, their chief sustenance from these swimming-crabs." It is not likely that whales feed on them, but from the immense shoals which occur in the seas round New Zealand, usually for several months of the year, it is certain that they constitute one of the commonest articles of food to the sea-birds and fishes of these seas. At the Portobello Marine Fish-hatchery the swimming form has been taken from the stomachs of the following fishes: Smooth-hound (*Mustelus antarcticus*), spined dogfish (*Squalus fernandinus*), warehou (*Seriolella brama*), red cod (*Physiculus bacchus*), hapuka (*Polyprion prognathus*), tarakihi (*Dactylosparus macropterus*), Maori chief (*Nothothenia macrocephala*), kelp-fish (*Coridodax pullus*), blue cod (*Parapercis colias*), spotty (*Pseudolabrus celidotus*), parrot-fish (*Pseudolabrus miles*), ling (*Genypterus blacodes*), and leatherjacket (*Pseudomonacanthus scaber*). Large deep-sea specimens (ground form) are commonly found in the stomachs of fish taken in depths down to 150 fathoms, though apparently they are most common between 20 and 30 fathoms.

LIFE-HISTORY.

Very little is known about the life-history either of this or of any other crustacean found in New Zealand. As far as has been observed, the female *Munida* extrudes its eggs in May or June. These are of a bright pale-green colour, and they are carried till the end of September or beginning of October, when they hatch out. The newly hatched larva is figured in the *Bulletin* of the Portobello Fish-hatchery (pp. 104–5). The subsequent development is scarcely known, but as early as the first week of November the free-swimming stage has been met with. At this time the individuals are very small, and contain very little pigment, the total length being about 20 mm., and that of the maxillipeds about 11 mm. These larvae have undergone many developments in the course of growth, and have lived for the greater part of the time at or near the bottom of the sea. As far as can be judged

from the hatching-time, this free-swimming stage is assumed in about a year. It is very improbable, judging from the development of allied forms, that larvae hatched in September or October can reach this stage in a month or two. When the larvae begin to swim freely the individuals gather together in schools of varying size. Small schools, consisting of a few thousand individuals, may be one or two yards across, but sometimes the aggregation is so great that vast shoals are met with, which colour acres of the sea-surface a bright red. These shoals extend for many miles. On their first appearance the specimens are small and almost transparent, except for a little red pigment, and they swim about independently. Gradually they congregate more and more till the large shoals are formed. These shoals move apparently in an erratic manner, but when any danger threatens them the mass of individual shrimps tends to move like one body, wheeling and curving like a flock of starlings on the wing.

OCCURRENCE.

Specimens of *Munida* have been taken in Otago Harbour in every month of the year, but the swimming stage known as "whale-feed," which is the only one which can have any commercial value, occurs chiefly from November to April. The occurrence is very erratic. This is shown by the records of the last few years, showing their occurrence in Otago Harbour: 1918—first appearance early in December. 1919—first appearance on 16th November; they were still abundant on 5th March, but disappeared about a fortnight later. 1920—first appearance on 9th December. 1921—first appearance on 2nd December. 1922—first appearance on 7th November.

COMMERCIAL VALUE.

In an average season such enormous quantities of these shrimps occur that at times they are thrown up on the beaches in millions. Masses of them, several inches deep, are thus heaped on the shore, and for weeks fill the air with an offensive smell. When collected and carted on to the soil they form a good manure.

During the course of development of the shrimps the body-tissues contain a varying amount of oil. Probably just before and during egg-formation the quantity of oil is greatest, but at this period most of the animals have gone to the bottom of the water, and it is only in a few of the swimming specimens that eggs are found. An attempt was made to collect specimens during every month of the year when they were available, and to ascertain the following facts in regard to them: (1) The quantity of oil present; (2) the nitrogen content; (3) the percentage of phosphoric acid. The extremely erratic occurrence of the organism during the last few years has, however, made it difficult to carry out the idea.

Before recording the results of the analyses made it is of interest to note what has been done elsewhere in attempts to utilize Crustacea for other purposes than for food. In his report on "Aquatic Products as Fertilizers," in the *Bulletin of the U.S. Commission of Fish and Fisheries* for 1904, Mr. Charles H. Stevenson says:—

"One of the most curious of the marine products used for fertilizer is the horseshoe-crab (*Limulus polyphemus*), which is found in abundance on the Atlantic coast, and especially on the shores of Delaware Bay. It has been used as a fertilizer for at least a hundred years. The crabs are

taken during May and June, when large numbers visit the shallow waters for spawning purposes. They are secured by picking them up at night on the shore either by hand or with pitchforks, or they are taken in pound nets constructed especially for the purpose. In 1880 the total catch in Delaware Bay amounted to 4,300,000 in number, worth $16,300; but the industry has steadily declined since then. These crabs weighed about 2 lb. each, and their value ranged from $4 to $8 per ton. In preparing them for fertilizer the entire crabs are sometimes merely stacked in piles until they putrefy and become somewhat dry, when they are broken into fragments and composted with muck, lime, or other suitable materials. Two or three small factories exist at which the crabs are dried and ground while green, and then mixed with sodium sulphate or sulphuric acid. The product sells for $15 to $25 per ton, and is an excellent fertilizer for grain and fruits. The output in 1880 approximated 1,950 tons; in 1890 it was reduced to 880 tons; and in 1901 it was still further reduced to 500 tons. . . .

"When lobsters were canned on the coast of Maine a desirable grade of fertilizer was made from the shells and other refuse from the canneries. This refuse was sold at a nominal price to the factories, or given away for the hauling. The farmers collecting it would usually dry and grind it, and then spread it on the land. Considerable quantities are thus used to-day near the lobster-canneries in Nova Scotia and New Brunswick. . . .

"The shells of shrimps produced in the fisheries of California and Louisiana are used to a considerable extent for fertilizer, which is employed by the Chinese not only on the Pacific seaboard but also on the Orient. The shells are removed from the dried shrimps and sold at about $5 per ton. In California they are especially valued in strawberry and vegetable culture, while in China their principal use is as fertilizer for rice: from 360 lb. to 400 lb. is commonly applied to each acre. It has also been used in wheat-growing, being spread broadcast on the land after the first ploughing."

In Europe various crustaceans are used as fertilizer, but no figures are available as to quantity produced or prices. Fritsch, in his work on *The Manufacture of Chemical Manures*, says: "Crab guano approaches fish guano. It is prepared from a species of sea-crab or lobster, of which there is enormous consumption on the coast of the North Sea. They are steamed, the substance pressed, then it is roasted on plates, and finally reduced to fine powder by grinding, like fish guano. It is in the form of a bright-yellow powder mixed with fragments of shells, and contains on an average 8 per cent. of nitrogen and 3 per cent. of phosphoric acid. . . . To appreciate the value of these manures it must be borne in mind that the greater part of their nitrogen exists not under the form of readily decomposable gelatine, but as a horny substance (chitin) which, moreover, always retains a certain amount of fat. These manures therefore act slowly; if spread in autumn they decompose sufficiently in winter to become active in spring, supposing always that they have not been buried too deeply."

CHEMICAL EXAMINATION.

Mr. W. Adams, curator of the Portobello Fish-hatchery, collected a large number of samples of specimens for us at different times. They were weighed out in lots of about $\frac{1}{4}$ lb. each, and placed in wide-mouthed bottles covered with gauze, and allowed to dry in air. The loss of weight varied

from 50 to 70 per cent., according to the length of time since capture. No doubt during this process a certain amount of nitrogen would be lost also, and a considerable alteration would take place in the fatty portion, while the shells of the animals—composed chiefly of chitin—would suffer little change. Owing to this alteration during slow drying we found it advisable to discard the analyses of most of this material and to deal with fresh specimens.

As already stated, the erratic nature of the occurrence of "whale-feed" during the last three years has prevented us from giving monthly values of the different ingredients. The following figures represent, therefore, the averages of several analyses:—

Composition of comparatively fresh Specimens.—Total moisture, 69·69 per cent.; dried material, 30·31 per cent.

Analysis of Dried Material.—Volatile matter, 91·49 per cent. (containing 7·19 per cent. nitrogen, equivalent to 8·73 per cent. ammonia); ash, 8·51 per cent.

Analysis of Ash.—Phosphoric anhydride, 1·7 per cent.; lime, 4·2 per cent.; alkalis (by difference), 2·61 per cent.

Estimation of Oil.—Ether extract, 14·17 per cent. of dried material; oil, 8·2 per cent.

Working from these figures we find that 1 ton of freshly gathered "whale-feed" would yield 679 lb. of dried material, from which could be extracted 55·7 lb. of oil. The residue would contain 48·8 lb. of nitrogen (equivalent to 59·2 lb. of ammonia) and 1 lb. (0·98 lb.) of phosphoric anhydride (equivalent to 2·14 lb. of tricalcic phosphate).

The value of such material is somewhat difficult to estimate. We are informed that the oil, extracted by benzine, would be worth in the wholesale market about 4s. per gallon; 55·7 lb. of oil (equivalent to 6·2 gallons) would therefore be worth £1 4s. 9d. Soluble nitrogen, as in ammonium sulphate, at present is estimated at £1 5s. per unit; and phosphoric anhydride in superphosphate at 8s. We consider it safer, however, to take £1 and 6s. 6d. respectively as a more reasonable estimate of value. At these rates the 48·8 lb. of nitrogen is worth £2 3s. 7d., and the small quantity of phosphoric anhydride only 3d. The total value, then, of the products from a ton of fresh "whale-feed" is probably about £3 8s. 7d.

It is clear from these figures that it would never pay to treat "whale-feed" as a commercial source of oil and manure, except occasionally perhaps in the immediate neighbourhood of a suitably installed plant for dealing with fish-offal. The capture of the fresh material would require the use of finer-meshed nets than are usually employed by any New Zealand fishermen. The handling of the fresh material, and the subsequent treatment of it—drying, oil-extraction, and grinding—would probably cost, at present prices of labour, plant, &c., not less than £2 per ton, and this would leave a margin of only £1 8s. 7d. per ton. It has further to be remembered that such a plant would only be available for treatment of "whale-feed" when there was a scarcity of fish—a contingency not very likely to happen, for when "whale-feed" are abundant fish are usually abundant also. We would further point out that already the production of nitrogenous manure in the frozen-meat industry of the Dominion is greater than the demand. From all these considerations we are of opinion that there is very little commercial value in "whale-feed" under present conditions.

LIFE-HISTORY OF THE NEW ZEALAND GRAYLING, *PROTOTROCTES OXYRHYNCHUS.*

By W. J. PHILLIPPS, F.L.S., F.R.G.S.

THE present paper contains a review of all published matter concerning the migrations and habits of the indigenous grayling, together with a number of new observations, collected, for the greater part, during a visit to the west coast of the South Island. There can be no doubt that before the introduction of trout the grayling was the most common fresh-water fish in many parts of New Zealand. It is now rarely seen except in isolated streams and rivers remote from settled areas. From a locality near Featherston the Dominion Museum recently secured two specimens which were taken in a hole in the river together with quinnat salmon, and considered to be the young of that species.

The grayling figured on the next page is taken from a drawing by J. Buchanan published to illustrate a paper by Hector (1871, p. 133). As the figure is a good representation of the species, it has been reproduced with a slight alteration to the shape of the profile of the head. On several occasions the author has been given unsolicited information regarding the existence of a second species of grayling in the streams of the west coast of the South Island. It was generally described as differing from the common species in having a dark-slate back, and pink and yellow on the sides.

The following illustrates the present state of our knowledge of the migrations of the New Zealand grayling :—

JANUARY.—Ascend the Hutt River in immense shoals ; females gravid (*Hector*). Commonly taken up-stream (*W. B. Braddon, C. Chitty, members of Westland Acclimatization Society, and others*).

FEBRUARY.—Make their appearance in Maitai River, Nelson (five miles from mouth) (*Rutland*). Common up-stream, Westland (*J. McKay and others—as in January*).

MARCH.—Go up to spawn : Nelson (*Rutland*). Becoming very fat and full of ova ; disappear this month : Waikato (*C. Chitty*).

APRIL. — Upokororo plentiful : Bay of Plenty (*Mair*). Have taken examples in Hokitika River estuary : Westland (*W. B. Braddon*).

MAY.—Two specimens taken in deep hole in Turanganui River, Featherston, and presented to Dominion Museum.

JUNE.—Appear up-stream, Nelson ; smallest 6 in. to 7 in., largest about 12 in. Ready to spawn (*Rutland*).

JULY.—Have taken specimens up-stream : Westland (*W. B. Braddon*). Disappear from minor tributaries and seek deeper water : Nelson (*Rutland*).

AUGUST.—No definite note of appearance.

SEPTEMBER.—Young taken ; Hokitika, migrating up-stream with whitebait (*W. B. Braddon*).

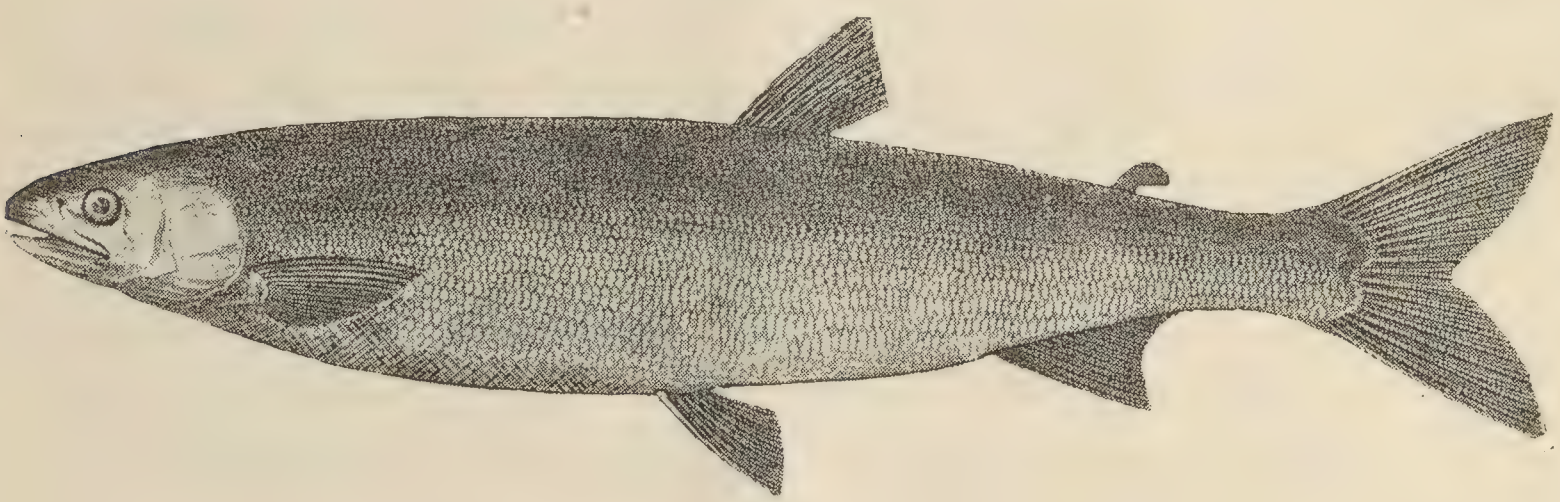
OCTOBER.—Young taken with whitebait : Westland (*W. B. Braddon and others*). Half-grown and adult fish appear at mouth of Maitai River, Nelson (*Hector*). Run up Waikato River (*C. Chitty*). Commence running, Taranaki streams (*W. H. Skinner*).

NOVEMBER.—In rivers in large numbers : New Plymouth (*W. H. Skinner*).

DECEMBER.—To be taken up-stream in large numbers (*J. McKay, W. B. Braddon, C. Chitty, and others*). Disappearing from rivers during this month : New Plymouth (*W. H. Skinner*).

As the evidence concerning the migrations of the grayling appears to be somewhat conflicting it will be well to consider how so many observers have given their record in such a diversity of manner over considerable periods of time. Generally speaking, there is no definite observation of the grayling in a very small stream except that given by Rutland; but even here it appears that Rutland's observations were made possible only on account of the fact that a mill-dam barred further progress up-stream for some days. Every observer would naturally note the appearance of the grayling in the particular part of the river with which he was familiar. The curious habit of this fish in congregating in shoals in deep parts of the stream or river would make observation difficult and in some places impossible. The angler who was accustomed to secure this species by means of an artificial fly during certain months would naturally conclude that, when the grayling failed to rise during other months of the year, it had migrated to another part of the stream, when in reality it may have been merely in the deeper water in mid-stream.

It appears probable that the food of the grayling is not the same all the year round. In this connection Te Manihera Waititi, a resident of



Whangaparaoa, near East Cape, and a noted observer, wrote to Mr. Elsdon Best in 1918: "They [the grayling] may be seen making their way to those portions of the streams in which there are cascades and rapids, and are often seen eating a growth from off the surface of the rocks and stones. This growth is commonly known to the Maoris as *reporepo*. The marks of their teeth may be seen on the rocks where the *reporepo* is growing. The grayling is still fairly common in certain streams near East Cape." It is possible that during certain months when adult insects are rare the food of the grayling consists largely of insect-larvae, various plants, algae, diatoms, &c., to be found in the bed of the river.

From reports collected by the author from anglers and residents of Westland there appears to be no doubt that grayling were common in holes in small streams during December, January, and February. Residents stated that until about six years ago this species was commonly to be seen exposed for sale in the Town of Hokitika during the above-mentioned months. The average weight was $1\frac{1}{4}$ lb., though specimens up to 3 lb. were occasionally seen. Natives of the Arahura Pa, Hokitika, referred to the smaller fish as *haparu*, and the large adult as *upokororo*.

In regard to the migrations as a whole, it is possible that the season of these migrations differs slightly in different localities. Though it apparently disappears from its usual summer habitat in March, Mr. Braddon has taken the grayling up-stream again in July. Specimens have been taken in the Hokitika River estuary in April. The observations

of Rutland are important as showing that in that locality at least the grayling runs into the smaller streams in June. This points to the possibility of two migrations annually. In view of the bulk of the above evidence it may be taken as conclusively proved that in most localities the grayling is common in streams during midsummer or immediately after, though it is possible that in midwinter the grayling may not always visit the smaller tributaries in such large numbers as observed by Rutland.

From June to October the grayling appears to migrate gradually down-stream to the estuary, remaining in deep water until the early summer months. All notes on the position of the grayling in October point to the fact that it has now migrated as far as the estuary. It is probable that in meeting with the salt water both the half-grown and adult fish have arrived at the limit of their journey and the return up-stream is imminent.

It will be seen that the only records of the grayling given during March denote that it is approaching spawning-condition. As the observations of Chitty were made on the Waikato River, it is interesting to note that these tend in some measure to agree with Rutland's statement that the grayling spawns in June. Hector's undoubted record of gravid females ascending the Hutt River in January shows that in that particular instance spawning was most probably taking place during January or shortly afterwards. As no other observations on the spawning-condition of the grayling have been made, the present suggestion is that the grayling spawns twice a year—once in midsummer, and again in midwinter.

It is not necessary to assume that during any part of its life-history the grayling migrates to the sea. The fact that no young under 5 in. have been observed is doubtless due to the fact that the grayling spawns far up-stream in the minor tributaries. The fry probably remain here until they have arrived at a certain size and then migrate down-stream. Considering the rate at which fishes of related families grow, the grayling 5 in. to 7 in. may be one year old, and those 10 in. to 12 in. two years and over.

Since the above was written it is interesting to note that on a recent visit to the Waiapu district, near East Cape (March, 1923), Dr. P. H. Buck secured between thirty and forty grayling in a funnel-shaped net set in the Waiapu River at a weir erected by the natives.

The author would welcome further information on this species.

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A MAORI KOROTETE, OR CORF.

By ELSDON BEST.

Illustration by J. McDonald.

THE corf was much employed in some districts, notably in the Whanganui Valley, in former times, for the purpose of keeping alive, for future use, eels taken in the ordinary eel-pot (*hinaki* and *punga*). It is still used to some extent in the latter district, the captive eels being fed with potatoes.

The corf, or korotete, for eels.

The illustration shows the squat form of these receptacles, differing much in shape from the *hinaki*, or trap-pot. This specimen was presented to the Dominion Museum by Anihana of Pipiriki, Whanganui River, in 1921.

The framework of this corf is composed of many hoops, formed by bending pliant rods (? of *manuka*) of about $\frac{1}{2}$ in. in thickness. These are placed about $1\frac{1}{2}$ in. apart. On the outer side of these are secured two series of covering-material, consisting of aerial rootlets of *kiekie* (*Freycinetia Banksii*) deprived of bark and carefully split down the middle, such splitting having been done with marvellous precision. These rootlets are deprived of bark by being drawn through a split piece of supple-

jack. One series of these split rootlets has been secured to the framework in a vertical position, the other in a diagonal manner. This work has been performed by an expert, being executed in a very neat manner. A well-made *taupoki*, or cover, conceals the opening of the corf, on either side of which is a loop. A small lug for handling purposes is seen on the sloping part of the side, and below it, on the vertical part of the side, is a wooden hand-grip lashed to the fabric.

Another specimen shows one series only of rootlets, all affixed in a diagonal manner and from $\frac{1}{4}$ in. to $\frac{1}{3}$ in. apart.

Two other names for this corf are *hinaki whakatikotiko* and *punga whakatikotiko*, as used in different districts.

STACKED FUEL IN A MAORI HAMLET.

By ELSDON BEST.

Illustration by J. McDonald.

THE illustration shows a much-favoured method of stacking driftwood (*tawhaowhao*) for drying, as adopted by natives. Arranged in this manner it is termed a *kotutu wahie*, or *whakatutu wahie*, meaning "firewood stacked on end." When stacked or corded horizontally it is called *apaapa*, *whakapapa*, or *taiki*. When stacked lengthwise to form the wall of a cooking-shed it is a *pahuki*. Thrown in a loose disorderly heap it is a *haupu wahie*.

DEPARTMENTAL REPORTS.

Chrysotile Asbestos in the Upper Takaka District.

By J. HENDERSON, Geological Survey Branch, Mines Department.

THAT chrysotile asbestos occurs in the Upper Takaka district has been known for many years, the first reference to its presence being in a report by Mr. William Gibbs,* Mining Warden; and in 1911 a paper on the Takaka asbestos by C. H. Holland† was published. It is associated with the basic and ultrabasic rocks that cover a broad zone extending north and south through the western portion of the Upper Takaka basin and into parts of the Aorere and Parapara valleys. The outcrops of these rocks are very erratic in distribution and size, owing to the original surface of contact between the igneous masses and the sedimentary beds they intrude being irregular, and owing to the variable amount of denudation that has since taken place. The country in which the rocks occur is high, rough, and broken, and is still for the most part inadequately explored. Last February an area lying to the north of the Mount Arthur Range, and drained by the headwaters of the Takaka River, by its branch the Cobb River, and by the Leslie River (a tributary of the Karamea), was hurriedly examined by the writer.

The Takaka River, at a point about five miles north of Mount Arthur, enters a large mass of serpentine which extends northward into the valley of the Cobb, a distance of at least three miles. The mining lease of 146 acres held by the New Zealand Asbestos Supply Company is situated in this area, about six miles due north of Mount Arthur. It lies on the western side of the Takaka River, the lowest part of the lease being about 1,700 ft., and the highest part about 3,000 ft., above sea-level. Access to the lease and to the district generally is poor. A pack-track sixteen miles in length extends from the end of the road at the Graham River forks, a point about two miles and a half from Pokororo Post-office, which is about nineteen miles south by road from Motueka. The track is steeply graded, rising from 470 ft. at the Graham River forks to 3,250 ft. at the Flora saddle, a distance of six miles. Another pack-track of good grade, and in part widened to a road, extends from Upper Takaka Township through the valleys of Waitui, Baron, and Grecian streams, branches of Takaka River, to the saddle between Ghost Creek (a small tributary of Grecian Stream) and the Takaka River. The track has been formed to this saddle, which is about 2,620 ft. above sea-level, but if extended a mile would junction with the track over the Flora saddle at a point about 2,270 ft. above sea-level. By this track the distance from the claim to Upper Takaka, which is on the main Takaka–Motueka Road, is slightly greater than to Pokororo, but the grade of the track is much easier than that across the Flora saddle. Upper Takaka (about 380 ft. above sea-level) is sixteen miles by an excellent road from the Port of Takaka.

The lease of the New Zealand Asbestos Supply Company has been cleared of forest; many cuts have been made through the surface soil, and the distribution of the chrysotile veins in, and their relation to, the enclosing rock is more easily studied here than in other parts of the

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* The Mining Industry, C.–2, p. 109, 1889.

† The Takaka Asbestos Deposits, *Mining and Engineering Review*, vol. 3, pp. 477–79, 1910–11.

serpentine mass. For these reasons most of the following observations were made in the company's lease; but asbestos occurs abundantly in other areas, and when the whole country occupied by serpentine has been explored and prospected other deposits of chrysotile will probably be discovered.

Serpentine is an hydrated silicate of magnesium containing a small amount of iron, and usually also of other metals, such as aluminium, chromium, nickel, and calcium. "Many unsustained [mineral] species have been made out of serpentine differing in structure (massive, slaty, foliated, fibrous), or, as supposed, in chemical composition; and these now, in part, stand as varieties, along with some others based on variations in texture, &c."* Chrysotile is one of the forms of serpentine which is distinguished from other varieties by consisting of fine, readily separable, flexible fibres with a silky lustre. It occurs (1) as "cross-fibre" and (2) as "slip-fibre." The "cross-fibre" chrysotile occurs in veins varying in width up to 3 in., and is arranged in them with the fibres at right angles to the walls. Only a small percentage of the fibre is over 1 in. in length, the great bulk of it being less than $\frac{1}{2}$ in. Usually the veins are arranged more or less concentrically round irregularly spheroidal or pillow-shaped masses of serpentine set in a variable amount of crushed and slickensided serpentine, and ranging in diameter from a few feet to apparently a chain or more. The vein-bearing rock forms a shell from 6 in. to, say, 30 in. thick, surrounding a core of serpentine with few or no veins. This core consists of dark-coloured rock which grades outward to light-coloured yellowish-green serpentine with chrysotile veins. In many of the smaller spheroidal masses small veins cross the core irregularly, and in larger masses penetrate some distance inward from the shell.

The "slip-fibre" occurs in the crushed rock between the spheroidal masses of serpentine. This crushed rock consists of irregular flaky pieces of serpentine with surfaces polished by the movements of the fragments against one another. A layer of parallel chrysotile fibres lies on, and is closely attached to, the polished surface, hence the name "slip-fibre."

In the western half of the claim the rock varies considerably, and the different kinds of serpentine appear to be arranged in irregular bands extending in an east-west direction. Thus along the northern boundary of the claim is a zone of irregular width, perhaps averaging 5 chains, of spheroidal masses or "boulders" of serpentine, 6 ft. to 10 ft. across, set in a small amount of crushed rock. Along the south edge of this zone the "boulders" increase in size, become more irregular in shape, and grade into great masses of serpentine, separated by narrow seams of crushed rock which contain "slip-fibre," and in places are bordered by serpentine containing veins of "cross-fibre." These large masses, which weather to a dark reddish-brown, stand out as rugged irregular blocks for 20 ft. to 40 ft. above the general surface, and form an easily traced zone that extends down the slope toward the Takaka River. Southward this band passes into another band of smaller "boulders," which in turn grades into a belt of intensely crushed serpentine along which Asbestos Creek has cut its upper course. In this crushed zone is a narrow irregular vein consisting of magnetite-grains impregnating rock along what is probably a definite plane of movement. South of this the rock is not so intensely broken, perhaps a quarter of the whole mass consisting of rounded masses of uncrushed serpentine. About 6 chains south from Asbestos Creek is a zone of coarse platy serpentine containing chromite irregularly distributed

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* J. D. DANA, *A System of Mineralogy*, p. 670, 1904 edition.

throughout. This chromite-bearing band, which strikes nearly east and west, is from 1 ft. to 2 ft. wide. A few yards south of it the rock consists of large spheroids with little intervening crushed serpentine. Still farther south is another zone of large "boulders," which in turn gives place to a belt of barren serpentine standing out above the general surface as rugged masses. The fact that these irregular zones are approximately parallel to each other and to a dyke of granite lying immediately north of the lease suggests that their distribution has a structural significance.

Recently Benson* has exhaustively discussed the origin of serpentine, and has shown that the majority of present-day geologists consider that serpentine is an alteration product of an originally intrusive olivine rock, often more or less pyroxenic, and that the hydration of the original rock was probably brought about by the agency of waters emanating from the same magma that produced the ultrabasic rock-mass. Some geologists, however, consider that the alteration to serpentine of the original rock is so conspicuously localized that it should be regarded rather as the result of the ordinary change of a mineral very susceptible to the action of water which may have been of surface origin. This matter is of more than academic interest, for chrysotile is one of the forms of serpentine, and the "cross-veins" and "slip-fibre" were almost certainly produced at the same time as the serpentinization of the mass of the rock, and the depth to which serpentinization occurs will mark the depth to which the chrysotile asbestos of any deposit is likely to extend. If the alteration is due to surface waters the serpentine will probably extend but a few hundred feet below the present surface; but if, as seems more probable, it was brought about by magmatic solutions it will extend to great depths.

Serpentines are formed by the hydration of rocks formed predominantly of pyroxene or olivine. According to Van Hise,† where serpentine is produced by the alteration of pyroxene there is an increase in volume of from 13 to 38 per cent., depending on the composition of the original pyroxene, the nature of the secondary minerals, and the amount of material removed in solution. Similarly, the increase in volume where olivine is serpentinized varies from 12 to 37 per cent.‡ Even allowing for the fact that the whole of the intrusive mass is not serpentinized, or is incompletely serpentinized, the increase in volume must be great, and the rock-movements caused thereby have produced the structure characteristic of the Upper Takaka serpentine—namely, rounded solid masses set in crushed and slickensided rock. Crosby§ plausibly suggests that the high relief of most serpentine masses is due to the forcing-up of the rock from below during slow and long-continued alteration.

The sequence of events leading to the formation of chrysotile asbestos was probably roughly as follows: After intrusion the ultrabasic rock crystallized, and on cooling developed extensive systems of shrinkage-cracks and joints similar to those occurring in massive granite. Solutions, highly charged with silica, carbonic acid, &c., given off by the underlying magma penetrated along these openings, and serpentinization began from the peripheral surface of each cuboidal block and penetrated inward. As the outer shells increased in volume, fractures opened concentrically round

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* W. N. BENSON, The Origin of Serpentine, a Historical and Comparative Study, *Amer. Jour. Sci.*, vol. 46, pp. 693–731, 1918.

† C. R. VAN HISE, A Treatise on Metamorphism, *U.S. Geol. Surv. Monograph No. 47*, p. 269, 1904.

‡ *Idem*, pp. 309–10.

§ W. O. CROSBY, Physiographic Relations of Serpentine, with Special Reference to the Serpentine Stock of Staten Island, New York, *Jour. of Geology*, vol. 22, pp. 582–93, 1914.

the unserpentinized cores; these became filled with serpentine (which experiments have shown to be readily soluble in carbonated waters) in the form of chrysotile. Meanwhile the expansion of many cuboidal masses caused rock-movements which crushed the soft outer serpentine shells and produced the slickensided rock with "slip-fibre" on the polished faces. Further hydration of the unaltered cores caused the formation of other concentric veins filled with "cross-fibre," and the process continued till all the rock was serpentinized or till the magmatic solutions were exhausted.

The examination, by no means exhaustive, made of the surface of the New Zealand Asbestos Supply Company's claim shows that a large amount of asbestos-bearing rock is exposed. Rough measurements of some of the asbestos-bearing shells round barren cores suggest that they contain percentages of "fibre" varying from 10 to 25 per cent., but no definite idea could be formed as to the proportion of barren core to fibre-bearing shell. In actual work the chrysotile-bearing rock could readily be separated from the barren, and the chrysotile contained in the shells is certainly much greater than that of the average rock milled in Canada. But in quarrying all the rock would have to be shifted, and the value of the claim depends on the amount of commercial chrysotile yielded by the crushed rock between the boulders. Some years ago officers of the Mines Department collected samples of rock and ascertained the percentage of "fibre" this kind of rock contained. According to Mr. Downey's tests, the crushed rock from Evans's cut (near north-west corner of the claim) contains 16·5 per cent. of fibre, and samples from Holland's cut (near centre of claim) 20·9 and 68·4 per cent. respectively. A sample taken by Messrs. Bishop and Barrance was found by the Dominion Analyst to contain about 15 per cent. of chrysotile. These results are certainly encouraging, and warrant the testing of bulk samples under commercial conditions.

The asbestos is apparently of excellent quality. In the veins it appears to be light yellowish-green in colour, but the fibres when separated are white. They have a silky lustre, are flexible and strong, and readily separate into extremely fine threads.

According to Cirkel,* it is impossible to ascertain the value of an asbestos deposit by diamond-drilling, on account of the fibrous nature of the rock: hence the driving of adits is recommended. The claim occupies steep hill-slopes, and is favourably situated for prospecting in this manner. Should the prospecting results be satisfactory, it could for the same reason be cheaply and advantageously worked by quarrying.

Notes on the Geology of the Nevis Valley, Otago.

By J. HENDERSON, Geological Survey Branch, Mines Department.

THE Nevis River, which drains a valley extending north-north-east in a nearly straight line for some thirty miles, and separating the Hector Mountains and The Remarkables on the west from the Garvie and Carrick ranges on the east, joins the Kawarau River about five miles down-stream from Gibbston and sixteen miles above Cromwell. For eight miles above the junction its course is through a rocky gorge in which the river falls from about 2,000 ft. to 840 ft. Above the gorge the valley opens to form

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* F. CIRKEL, Chrysotile Asbestos, its Occurrence, Exploitation, Milling, and Uses, *Canada Department of Mines, Mines Branch, Bull. No. 69*, p. 96, 1910.

a depression or basin six miles long and from one to two miles wide, in which the river has formed a wide flood-plain and extensive terraces; toward the upper end is the Lower Nevis Township, about 2,250 ft. above sea-level. Above Lower Nevis the river traverses a straight narrow gorge three miles and a half long, beyond which the valley again increases in width. This, the Upper Nevis Valley, at its lower end is about 2,500 ft. above sea-level and about a mile wide. Extensive flats and terraces occur, the highest of the latter being fully 600 ft. above river-level.

The Nevis Valley is difficult of access. The very steeply graded road from Bannockburn and Cromwell crosses the broad summit of the Carrick Range at a height of about 4,250 ft. above sea-level. Another road leads across the saddle (3,250 ft.) at the head of the Nevis from the Nokomai Valley, by which Garston, on the Kingston–Invercargill Railway, is reached. A saddle-track crosses the Hector Range from Kingston to the Upper Nevis by a col nearly 5,500 ft. high. Another track which rises well over 2,000 ft. above sea-level connects the Lower Nevis with Gibbston. These routes, all of which traverse miles of high uninhabited country, are, during the winter months, liable to be blocked by snow.

Hydraulic sluicing and elevating are extensively carried on in the Nevis Valley, especially in its upper portion, where at the present time (December, 1922) six claims are at work. In the Lower Nevis one party is sluicing near the township, and a dredge is working some four miles down the valley. From the end of May till the end of August the sluicing claims close down owing to the frosts; and if the winter falls of snow on the mountains are scanty the supply of water during part of the summer may fail.

McKay,* in 1894, pointed out that the Nevis River had carved its valley along a fault-zone. The valley, in fact, is of tectonic origin, and consists of a narrow trough let down between larger rock-masses that form the mountains on either side. These mountains are formed of the ancient schists that cover such large areas in Otago; but Tertiary rocks, crushed and contorted by the movements of the major blocks, and in part concealed by later gravels, occur along the valley, preserved from erosion by deep involvement in the fault-zone.

Tertiary rocks cover several square miles at the northern end of the Lower Nevis basin. They extend from two miles south-west of the bridge over the Nevis River north to Little Creek, a distance of three miles and a half, and consist chiefly of carbonaceous shales 200 ft. to 300 ft. thick, toward the top interbedded with thin bands of micaceous and sandy shale. Higher in the sequence there is a thick seam of lignite, which is overlain by fine white sandstone not well consolidated. Fossil leaves occur in places in the carbonaceous shale. These beds are much contorted and folded; the folding is along north-and-south lines, and is connected with the main structural faults of the district. Small areas of Tertiary rocks occur on the eastern side of the Nevis River, from about 60 chains south of the bridge to near the Coal Creek East junction, where the beds lie flat, and again as a narrow discontinuous strip from opposite the township along the foot of the hills south to Commissioner Creek, where for the most part they dip steeply to the east.

Only the northern end of the Upper Nevis basin was visited by the writer. Along the western side of the valley, and separated from the present flood-plain by a narrow ridge of schist, are outcrops of lignite

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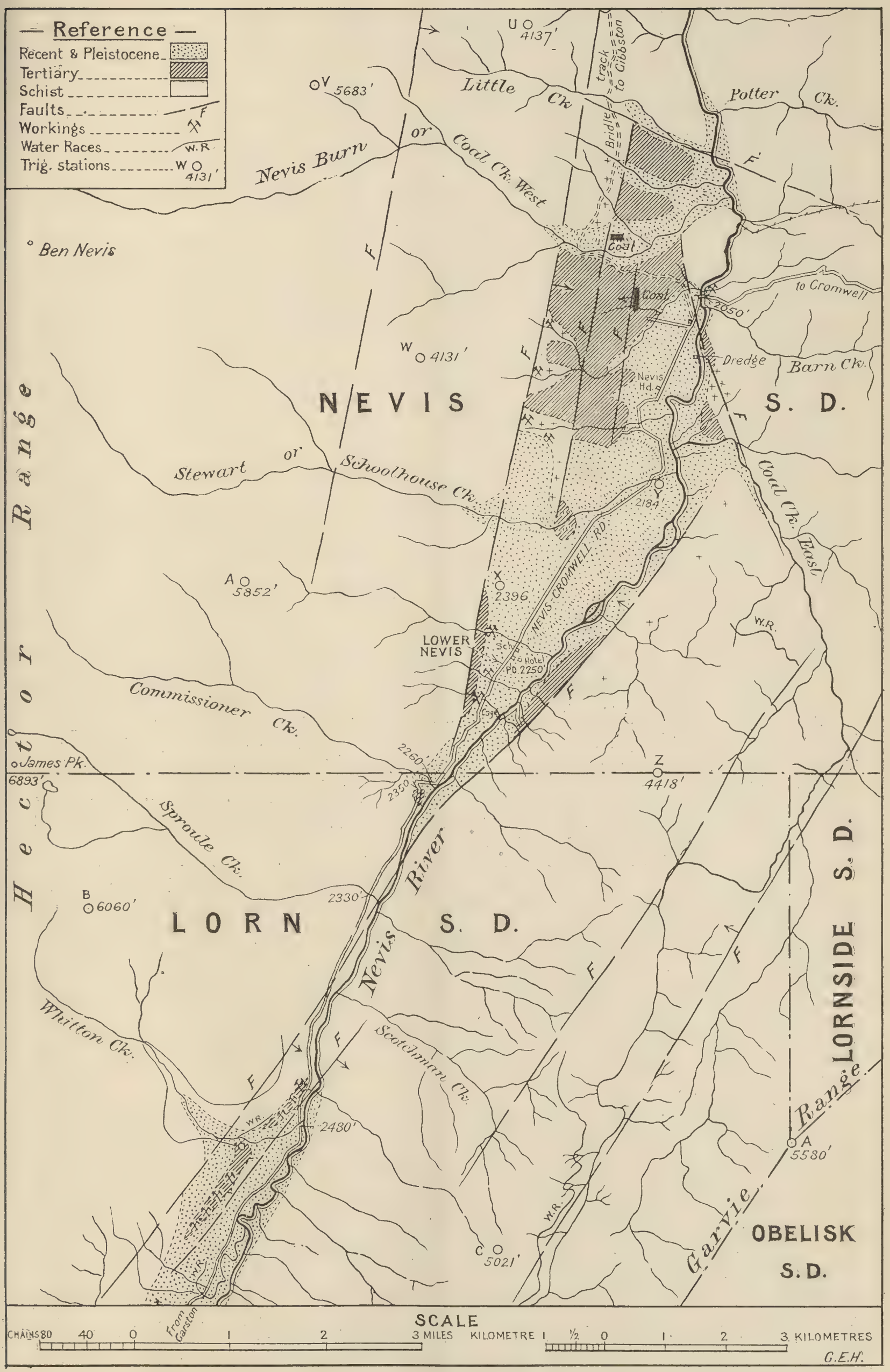
* A. McKAY, Older Auriferous Drifts of Central Otago, C.–4, pp. 11, 12, 1894. This report was reprinted in pamphlet form in 1897 (see pp. 29–33).



GEOLOGICAL SKETCH-MAP OF THE NEVIS DISTRICT.

associated with fine sandstone and shale, all standing vertical and striking north-north-east. Well-consolidated gravels are also involved in the faulting. These overlie the coal-bearing beds, but their exact relation to them is not known.

In the sluicing claim immediately south of Whitton Creek three sets of gravels are well exposed. Unconsolidated relatively coarse terrace-gravels form the upper 12 ft. to 20 ft. of the face worked. These unconformably overlie well-consolidated gravel, consisting chiefly of rounded oxidized schist-fragments and small subangular pieces of quartz set in a matrix of brownish-yellow sandy clay with lenses of sand. On and near the "bottom" are large irregular but smoothly rounded boulders, known as "chinamen." These masses are derived from the Tertiary beds, and consist of quartzose sand or gravel cemented into a particularly hard concretionary mass by the deposition of a siliceous substance, probably chalcedony. This layer of gravel, which is at least 30 ft. thick, constitutes the gold-bearing "wash," although the overlying unoxidized terrace-gravel also contains a little gold. The "false bottom" on which it rests dips at about 25° westward. The underlying gravels, which are also oxidized and well consolidated, differ in that they are relatively finer and contain a much larger proportion of quartz-fragments, but fewer "chinamen" and decidedly less gold. These gravels rest on oxidized schist that forms a narrow ridge immediately to the east of the claim. At the south end of the claim the "wash" abuts against vertically disposed coal-measures consisting of white fine-grained quartz sand overlying black carbonaceous shale and lignite. The gold-bearing gravels do not dip steeply, but at the contact with the coal-measures are more or less disturbed, and were evidently deposited before fault-movement had ceased.

A section similar to the above, showing gold-bearing oxidized gravels resting on a narrow exposure of schist, and dipping gently westward to vertical coal-measures, was observed in the sluicing claim between Whitton Creek and the northern end of the Upper Nevis basin. Here, however, a considerable thickness of clay is associated with the wash, and renders the working of it more difficult.

In the Lower Nevis basin the claim near the township is working on the unoxidized gravels of the flood-plain; but steeply-dipping, well-consolidated brown gravels containing a large proportion of small quartz-fragments have been well exposed along the foot of the hills. The abandoned claims extending along the edge of the hills north of Stewart Creek were in shallow oxidized wash overlying schist, or a brown well-consolidated schistose gravel containing large subangular pieces of schist as well as a large proportion of small quartz-fragments. This lower gravel rested on schist.

Other workings in the Lower Nevis basin and along the gorge between the basins seem to have been in the loose gravels of the stream-beds or in the bordering terraces. Such are the workings in Coal Creek West and on the east side of the Nevis near the bridge on the Cromwell Road. Seven dredges were at one time at work in the Nevis Valley; only one is now in commission. Much of the flood-plain of the river both in the upper and lower basins has been worked. The ground was shallow, and the bottom usually a brown gravel or rocks of the coal-measure series. It should be noted that the alluvial gold obtained from the loose flood-plain and terrace-gravels is fine, whereas that from the older oxidized and well-consolidated gravels is coarse.

McKay, in his report on "The Older Auriferous Drifts of Central Otago," showed conclusively that most of the gold won in Otago was

obtained either directly from quartz drifts of Tertiary age or from gravels that had been enriched by gold shed from such quartz drifts. He divided the quartz drifts and the breccia conglomerates with which they are associated in many places into five series; those of the Nevis Valley, together with the coal-bearing strata, he placed in his "Fresh-water" Series of Upper Tertiary age. No section showing clearly the relation of the quartzose gravels to the coal-measures was observed during the present visit, and McKay describes none; but the fact that siliceous concretions ("chinamen") derived from the coal-measures occur in the quartzose gravels prove conclusively that the latter are unconformably younger than the former, and they are therefore placed in McKay's "Newer Breccia Conglomerates and Quartz Drifts," the series immediately overlying the "Fresh-water" formation. McKay states that no quartzose drifts or coal-measures occur in the Upper Nevis basin, but both have since been uncovered in the sluicing claims.

Fragmental cinnabar is associated with all the alluvial gold of the Nevis Valley. In the lower basin it is present in small amount and in a very fine state of subdivision. It is coarser in the upper basin, and increases in coarseness and quantity at the head of the river. Probably it is derived from a lode near the Nevis–Nokomai saddle, the same lode perhaps shedding the cinnabar occurring in the Nokomai Valley.

As already stated, the lignite-seams of the Nevis Valley rest on shales, and are overlain by white, fine-grained, and poorly-consolidated quartz sand. The principal outcrops are near the northern end of the lower basin. At Ritchie's coal-pit, rather more than half a mile west of the bridge, a seam from 60 ft. to 80 ft. thick, striking nearly north, and dipping west at 75°, is worked opencast. The seam, which crosses a series of low hills rising from the river-flat, has its outcrop largely concealed by soil and vegetation. Northward it disappears, probably owing to faulting, since 10 chains north of the pit prospecting has shown it to be represented by an irregular band of dark pug containing fragments of lignite. Still farther northward on the north side of Coal Creek West thick coal has been exposed by the gold-workings. South of Ritchie's pit the coal has been mined at points west and south-west of Nevis Homestead. Coal-measures also outcrop on the north side of Stewart Creek. These occurrences are probably all on a single fault or structure line. About 10 chains west of Ritchie's pit is another outcrop of coal of unknown thickness, perhaps a repetition of Ritchie's seam by faulting.

Coal, lying flat, outcrops on the east side of the river a mile south of the bridge on the road to Cromwell, and, over several acres, formed the bottom on which the dredge worked. The thickness of the seam is unknown, but is considerable. A thick seam outcrops across the river east of Lower Nevis Township. It rests on shale, is overlain by fine white sandstone, and dips steeply eastward. Crushed coal, probably part of the same seam involved in the same fault, which extends north-north-east along the foot of the range east of the river, outcrops a little south of Commissioner Creek, nearly two miles south-west of the township.

In the Upper Nevis basin crushed fine white sandstone standing on end and containing streaks of carbonaceous shale has been exposed by sluicing immediately to the west of the wash at the claim north of Whitton Creek. Similar beds occur in the same attitude at the first claim south of Whitton Creek. Here also are fragments of coal up to 6 ft. thick and a chain long which are mined for fuel.

The following analyses of coal from the Nevis Valley are available :—

	(1.)	(2.)	(3.)
Fixed carbon	25·36	35·00	7·30
Hydrocarbon	47·12	38·65	40·50
Water	22·12	22·00	13·80
Ash	5·40	4·35	38·40
	100·00	100·00	100·00
Sulphur	0·48	0·39	0·13

(1.) Nevis coal-pit. Seam 30 ft. thick (*Dom. Lab. 40th Ann. Rep.*, p. 59, 1907). The writer was informed by local residents that this sample was collected by the Inspector of Mines from the pit on the east side of the river opposite the township.
(2.) Ritchie's coal-pit, west of bridge on Cromwell Road. Seam 60 ft. thick.
(3.) Seam 1 ft. thick, consisting of small fragments of coal, resin, and sand, occurring in the coal of Ritchie's pit. Several of these seams are reported to be interbedded with the coal of this locality.

Carbonaceous shale several hundred feet thick forms the lowest known Tertiary beds of the Lower Nevis basin. In the Upper Nevis basin a similar shale which underlies the coal seems to be present in small amount. The shale varies in colour from light to dark brown, but is weathered for 2 ft. or 3 ft. from the surface to a uniform pale greyish-buff; on exposure freshly broken shale assumes this tint in a few days. The rock splits readily, but is exceptionally tough, perhaps owing to the fact that it contains a large proportion of minute mica flakes. Fossil leaves occur in some layers, and carbonaceous matter in all. Some of the darker bands when freshly broken have a petrolaceous smell, and, so far as known, all the shale yields mineral oils on distillation, but no layer has been found that contains oil in profitable amount. A little prospecting has been done, and an adit driven into the shale for about 50 ft. This adit, however, is driven along the trough of an irregular syncline where the strata are nearly horizontal, and explores but a small thickness of shale.

Seven samples of shale forwarded by Mr. S. Graham have been tested in the Dominion Laboratory, with the results given in the accompanying table :—

	(1.)	(2.)	(3.)	(4.)	(5.)	(6.)	(7.)	(8.)
Fixed carbon	4·60	3·85	2·95	1·70	4·10	3·90	3·95	20·15
Volatile hydrocarbons ..	18·90	17·25	17·75	13·55	19·50	23·50	20·50	
Water lost at 100° C. ..	5·10	5·35	5·25	5·25	5·00	4·10	4·00	9·10
Ash	71·40	73·55	74·05	79·50	71·40	68·50	71·55	70·75
	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00
Sulphur (per cent.) ..	0·71	0·68	0·74	0·48	0·64	0·66	0·63	..

Of these samples four were taken at 10 ft. intervals along the adit, the other three being from surface outcrops. The analyst tested a mixture of equal quantities of these seven samples for the oil content and found it to contain—

	Gallons per Ton.
Below 200° C.	3·5
200–300° C.	4·4
300–375° C.	5·3
Total oil	13·2

Nos. 1 to 7, *Dom. Lab. 55th Ann. Rep.*, p. 11, 1922. No. 8 is an analysis of a sample taken by the Inspector of Mines. It contained oil to the amount of but 3 gallons per ton.

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THE PRESENCE OF VITAMIN B IN FROZEN FLESH FOODS.

By A. M. WRIGHT, A.I.C., F.C.S.

A CONSIDERABLE amount of work has been recorded in connection with the vitamin content of fresh and canned meats (1, 3, 6, 7), but none appears so far to have been reported upon meats which have been subjected to cold storage (5). The present paper is a record of an investigation carried out in order to determine the effects of up to nine years' cold storage upon the vitamin B present in beef, mutton, lamb, and pork, the temperatures during cold storage ranging from 2° to 15° F.

The experimental work carried out in connection with the determination of the vitamin content of the foods examined was done as feeding-experiments upon young growing animals—in this instance White Leghorn cockerels from two to three weeks old at the beginning of the experimental feeding were employed.

In the determination of the vitamin content of the meats the experimental animals were fed upon a diet in which the protein was derived wholly from the meat, the fat from the meat supplemented with lard, also butterfat, the carbohydrates from purified starch. In the diet of the control animals the protein was derived from purified casein, the carbohydrates from purified starch, the fats from lard (heated), with or without the addition of butterfat, in accordance with the attempt to add or withhold vitamin A; compressed yeast was used to supply the vitamin B where required in the diet of the control animals. All animals, control and

experimental, received a mixture of inorganic salts, and, in order to supply the vitamin C, orange-juice, and latterly swede-juice, was given to all animals; the inorganic-salt mixture was that of Osborne and Mendel (2). All animals were allowed water *ad lib.*

The protein, carbohydrate, and fat contents of all the materials used for the diets were determined in order to adjust the ration balance accurately. Owing to the varied composition of the materials used in the different diets, especially those in which the meats formed an essential part, it was found more practicable to prepare each diet so that the daily ration for each animal contained the following: Protein, 2·7 grams; carbohydrates, 8·25 grams; fat, 3 grams; inorganic salts, 0·75 gram.

In all cases the rations were minced or finely ground, and so mixed that the individual ingredients could not be picked out and eaten separately by the animal. After mixing and thoroughly incorporating the ingredients of a given diet, the mass, after weighing, was divided into cubes each containing one-third of a daily ration; these were then packed in small boxes and placed in cold storage, to be drawn upon as required. In the case of the experiments with fresh meat, it is apparent that at the end of the feeding-period (sixty days) such meat had been in cold storage two months: this fact, however, did not detract from the value of the results obtained during the experiments recorded.

In the course of the investigation a considerable amount of difficulty was experienced until a knowledge of various factors was acquired in regard to the handling and feeding of the animals. In addition, disease and accident necessitated that certain results should be repeated, despite the fact that each experiment was carried out at least in duplicate, and in many cases with four animals.

All animals dying during the course of the investigation were submitted to *post mortem* examination; in addition, normal and control animals were killed for information from time to time during and at the conclusion of the investigation.

Each animal (identified by means of a numbered leg-band), morning and evening, was fed separately in an individual cage; during the rest of the day all animals were kept in a common run; any animals, however, which showed evidence of ill health during or in consequence of the experimental feeding were placed in a separate compartment until recovery or death.

As no recorded results were available in regard to either the effect of artificial diets or the effect of deficiency in vitamin B upon the animals used, a course of feeding-experiments was carried out in order to ascertain the effect of these factors upon the health and growth under the experimental conditions.

The control experiments were carried out with animals fed upon a diet composed of purified casein, starch, lard, butterfat, and the salt mixture, in the proportions indicated by the daily ration noted above; there was added equal to 0·4 gram dried yeast, together with the juice of swede turnips.

Upon this diet a continuous and satisfactory growth and increase of weight were shown during sixty days; none of the symptoms of polyneuritis was present in any of the birds in this series of control. The

average weekly weight in grams during the sixty days was as follows: 161, 165, 177, 214, 247, 300, 302, 321, 333.

With the diet noted above, but without yeast, thus providing a diet deficient in vitamin B, the animals failed to gain weight, and died in about sixteen days, but without exhibiting any definite symptoms of polyneuritis. The average weekly weight in grams during the period was as follows: 164, 166, 173, 161 (died).

When a mutton-fat heated for six hours in the air was substituted for butterfat and lard in the above ration, thus producing a diet deficient in vitamin A, the animals showed but little growth and but slight increase in weight, death resulting in from twenty-eight to thirty-five days; the animals were emaciated, despite the fact that they readily ate their full diet in amount equal to that of the first group. The average weekly weight in grams during the period was as follows: 161, 154, 156, 167, 180, 181 (died).

With the diet noted above, but with the substitution of a mutton-fat heated in air for about six hours, and without yeast (a diet deficient in both vitamins A and B), the animals lost weight rapidly, and died in about ten days, falling from 160 grams to 109 grams during the period. In this group it should, however, be noted that the animals ate but little of their ration after the first five days.

The results of the control experiments are summarized in the following table:—

Table 1.—Controls.

Present .. .. / Deficient	A, B, C. ..	A, C. B.	B, C. A.	C. A, B.
	Grams.	Grams.	Grams.	Grams.
Original weight ..	161	164	161	160
7–10 days	165	166	154	109 (died)
10–14 ,, ...	177	173	156	..
21 ,, ...	214	161 (died)	167	..
28 ,, ...	247	..	180	..
35 ,, ...	300	..	181 (died)	..
42 ,, ...	302	..	..	..
49 ,, ...	321	..	..	..
60 ,, ...	333	..	..	..

In the main experiments various meats were substituted for the casein and for a portion of the lard used in the diets for the control animals, but the proportions were adjusted in order to give a similarly balanced ration. These experiments were designed to determine the presence or absence of vitamin B in the fresh meats used, and also to determine whether cold storage destroyed this substance under the conditions of ordinary commercial practice. The animals fed upon the fresh meats also served as a check upon any dietary conditions which might arise in the course of the feeding. The meats used were fresh lamb, three-years cold-storage lamb, fresh mutton, fresh beef, two-years cold-storage beef, nine-years cold-storage pork.

The following table shows the results of the average weights in grams recorded each week in the course of the experiments :—

TABLE 2.—FRESH AND FROZEN MEATS.

——	Controls.	Lamb.		Mutton.	Beef.		Pork.
		Fresh.	Three Years' Cold Storage.	Fresh.	Fresh.	Two Years' Cold Storage.	Nine Years' Cold Storage.
	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.
Original weight	161	180	169	197	153	169	173
7–10 days ..	165	178	168	187	154	175	201
10–14 ,, ..	177	170	171	211	151	156	209
21 ,, ..	214	220	200	217	183	185	249
28 ,, ..	247	237	229	265	194	209	284
35 ,, ..	300	256	267	298	227	222	286
42 ,, ..	302	302	304	..	247	245	295
49 ,, ..	321	305	308	..	264	268	343
60 ,, ..	333	349	344	..	313	315	352

From one series of experiments it was found that when animals were fed upon a diet deficient in vitamin B for fourteen days and until loss in weight was definitely found, and then fed upon the three-years cold-storage lamb ration, recovery was made, and apparently a cure of the deficiency symptoms was effected, although the recovery was slow; and at the end of sixty days the animals showed weights only equal to those which were about thirty-five days on the three-years cold-storage lamb ration from the beginning.

In connection with the results shown with the foods containing meat, it was found that in nearly all cases the animals for about fourteen days either lost weight or remained stationary as regards their weight; thereafter, however, steady and continuous growth was maintained. The principal exceptions were those animals in which pork was included as part of the ration. Had the condition noted been found with all classes of meat it might be suggested that the meat ration itself was responsible; but, in view of the position disclosed with the pork-fed animals, some other explanation must be sought; later it is hoped that some solution will be found.

From the results of the experiments it is found that cold storage up to nine years at temperatures ranging from 2° to 15° F. does not destroy, nor, as far as can be determined, does it affect, the vitamin B of meats.

This investigation was carried out in the Biological Department of Canterbury University College, and in the chemical laboratory of the New Zealand Refrigerating Company (Limited). The funds to enable it to be done were voted from the Government research grant on the recommendation of the New Zealand Institute.

The author desires to express his thanks to Dr. Charles Chilton, Professor of Biology, Canterbury University College, and to Dr. A.B.

Pearson, Pathologist to the Christchurch Hospital, for assistance given during the work.

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THE PRESENCE OF VITAMIN A IN FROZEN PORK.

By A. M. WRIGHT, A.I.C., F.C.S.

IT has been a matter of dispute as to whether lard can be regarded as a source of vitamin A, but it is now considered that the differences found in the experimental results can be explained by a consideration of the class of feeding-stuffs fed to the pigs (1)—that is to say, whether such foods supplied the pig with vitamin A in amounts which would enable the animal to store this vitamin in the fatty tissues used for the manufacture of the lard; in addition, it may happen that any vitamin A originally present in the pork-fat has been destroyed by the processes employed in manufacturing the lard.

In the experiments to be described no consideration has been given to the nature of the feeding-stuffs originally fed to the pig, for the reason that the pork which was used had been in cold storage for nine years; nor is the question of the process of manufacturing involved, for the pork was fed to the experimental animals in a raw state, mixed with the other dietary constituents.

It has already been reported that vitamin A in butter is not destroyed by cold storage (2), but the report does not disclose the temperature to which the butter was subjected, nor the length of time during which it was held in cold storage.

In a former paper (3) the author has described the method of the experimental work in determining the presence of vitamins in cold-storage meats, and the nature of the controls adopted to ascertain the effect upon the animals used of diets known to be deficient in vitamins A and B;

a similar course was adopted in the experiments covered by the present paper.

In the experiments determining the presence of vitamin A the animals (White Leghorn cockerels from two to three weeks old) were fed upon a diet composed of pork containing 25 per cent. fat, starch (with and without butterfat for control purposes), and a salt mixture as described in the former paper; the juice of swede turnips was also given.

The following table shows the results of the average weight in grams recorded each week for the control and experimental animals :—

	Controls.		Pork with Butterfat.	Pork, no Butterfat added.	Pork, Butterfat (first 28 Days only).
	A, B, C present.	A deficient.			
	Grams.	Grams.	Grams.	Grams.	Grams.
Original weight ..	161	164	179	169	168
7–10 days ..	165	166	195	201	197
10–14 ,, ..	177	173	206	225	213
21 ,, ..	214	161 (died)	241	268	258
28 ,, ..	247	..	277	279	290
35 ,, ..	300	..	279	296	302
42 ,, ..	302	..	295	300	315
49 ,, ..	321	..	346	338	342
60 ,, ..	333	..	350	347	360

In planning the experiments the author had considered it unlikely that vitamin A was present in the pork, and to a certain extent the animals fed upon the pork without the addition of butterfat were to have been regarded as controls to show the effect of a vitamin A deficiency. The results, however, clearly show that even after nine years' cold storage at from 2° to 15° F. vitamin A remains active.

This investigation was carried out in the Biological Department of Canterbury University College, and in the chemical laboratory of the New Zealand Refrigerating Company (Limited). The funds to enable it to be done were voted from the Government research grant on the recommendation of the New Zealand Institute.

The author desires to express his thanks to Dr. Charles Chilton, Professor of Biology, Canterbury University College, and to Dr. A. B. Pearson, Pathologist to the Christchurch Hospital, for assistance given during the work.

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PETROLEUM AT WAIOTAPU, KING-COUNTRY.

By Professor JAMES PARK, Otago University.

IN 1921 I examined oil-seepages on the east bank and bed of the Waiotapu Stream, in Section 4, Block III, Paeroa Survey District, and at other places in the neighbourhood.

The most prolific seepages occur at the ford on the cross-road between the Taupo and Galatea main roads. On the flat sinter-crusted platform on the east bank of the stream, a few yards down-stream from the ford, there are many small circular holes filled with hot water, through which there rises an intermittent stream of bubbles of non-inflammable gas accompanied by blebs of oil. Around the rim of these gas and oil springs there is an incrustation of dark-brown or chocolate-coloured ozokerite, ranging from a mere film to 2 in. thick. In the bed of the stream, at the ford itself, there occur many emanations of gas and oil. The oil breaks at the surface of the water as amber-coloured rings, and then floats down-stream as iridescent films. The gas and oil emanations near the ford occur over an area of some 25 yards long and 10 yards wide. By the simple expedient of pushing a rod a few feet into the silt and mud on the stream-bed a strong evolution of gas and oil may be obtained. Half a mile up-stream from the ford emissions of non-inflammable gas and oil are plentiful, especially on the west bank.

The Waiotapu area lies in the Rotorua-Taupo volcanic zone, and, since the surface rock is a rhyolitic tuff, the origin of the gas and oil presents a problem of unusual economic importance.

The Middle Tertiary coal-bearing rocks occur in the Waikato-Waipa country to the west of Waiotapu, where they are seen to disappear below the rhyolitic tuff. They consist of a tremendous pile of conglomerates, sandstones, limestones, and argillaceous strata, and occupy an area many thousand square miles in extent.

To the east of Galatea the Tertiaries rise from below the rhyolitic tuffs. All the evidence tends to support my view that they underlie the whole of the central volcanic region of the North Island.

The gas and oil emanations occur along the course of the Waiotapu fault, the existence of which was first recognized by Hochstetter.

As the result of my examination I concluded that the brown coals of the underlying Tertiaries are the most probable source of the gas and oil.

In a report* on the Waiotapu oil-seepages Percy G. Morgan, M.A., F.G.S., states that he observed in the rhyolitic tuff numerous fragments of carbonized wood having approximately the composition of brown coal. This carbonized wood, he thought, was capable of yielding gas and oil on being distilled at moderate temperatures. He mentions that Dr. J. M. Bell, in a memorandum dated 21st November, 1910, suggested a similar explanation for the oil occurring in the Waiotapu district.

Fragments of carbonized twigs and branches of trees are certainly numerous along the banks of the stream, embedded in the rhyolitic detritus derived from the tuffs, but I observed no fragments of carbonized wood in the rhyolitic tuff itself. They may possibly be present, though it seems difficult to believe they could occur in such abundance as to

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* *Sixteenth Annual Report, N.Z. Geological Survey,* 1922, p. 13.

yield the supply of gas and oil that comes continuously to the surface in the floor of the Waiotapu Valley.

I may say that the association of volcanic extrusions and oil is well known in some important oilfields. Moreover, Beeby Thompson, an oil-geologist of world-wide experience, states that if oil is found seeping from volcanic rocks the source of the oil must be looked for in the underlying strata. It is more than probable that the vulcanicity and waning thermal activity along the Rotorua-Waiotapu fault is not the cause of the faulting, but an expression of the powerful crustal dislocation that towards the west terminates abruptly the Mesozoic rocks of the Kaimanawa Mountains. Profitable oilfields occur along fault-planes in Burma and elsewhere.

If the Tertiaries underlie the rhyolitic tuffs, as seems most probable, the prospect of finding profitable pools of oil is, in my opinion, sufficiently promising to warrant boring at judiciously selected sites.

PLATINUM IN ALLUVIUM FROM NELSON MINERAL-BELT ROCKS.

By W. F. WORLEY.*

SOME time ago a small quantity of white metal was sent to me, indirectly, for identification. It proved to be platinum alloy of 93 per cent. purity. As this was an important find for this district, an endeavour was made to get into touch with the prospector who had discovered it. By entering into a confidential agreement I was able to do so. Having been released from my bond of secrecy, I am now able to give the history of this discovery.

The prospector who discovered it was Mr. Richard Hart, of Richmond and the Lee River, a tributary of the Roding River, the place where it was found. (Strictly speaking, the spelling should be *Lea*, not *Lee*, for these two rivers were evidently named after the Lea and the Roding Rivers of Kent, which enter the River Thames a few miles below London Bridge.)

The Lee River cuts right across the Mineral Belt, but so far platinum has been discovered only in that part of the river below the Mineral Belt, all prospecting in the upper part of the river, beyond the Mineral Belt, having been fruitless. The ultra-basic rocks of the Mineral Belt, therefore, appear to be the source of the platinum. So far, only small quantities of platinum have been obtained, and these were got chiefly from crevices in Maitai-slate rock, exposed on edge in the river-bed. A re-sorting of the boulders and gravel which previously formed the river-bed has taken place, and probably the platinum now found in the rock-crevices is a result of this re-sorting action. It may, however, have been deposited in the crevices while the gravels, which have since been removed, were being laid down. In support of this view it may be stated that crevices containing recent river-wash have not yielded platinum.

In the Lee Valley there are several river-terraces rising one above the other. The most recent of these now forms the river-bank, and in places this terrace is still being eroded away. In the gravels of this lower

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* Mr. W. F. Worley died at Nelson, 4th August, 1923.

terrace there are patches of dark rusty-brown earth, which are evidently the residuum of a boulder of an ultra-basic rock. Some of these rusty patches have yielded a speck or two of platinum, lending further support to the view that the platinum in the river-bed has been derived from the ultra-basic rocks.

When Mr. Hart discovered this platinum in the Lee River it was supposed to be an absolutely new find for that locality. By a strange coincidence, however, it was discovered that platinum had been found there more than fifty years previously. My son, now Professor Worley, was studying at the Technological Institute, South Kensington, London. In one of my letters to him mention was made of the very important discovery of platinum made in this district. He was acquainted with a Mr. John Sellon (now deceased), who at that time was a member of the firm of Johnson, Matthey, and Co., London, the well-known platinum-merchants; and my information was communicated to him. Mr. Sellon then narrated to my son that one of his younger brothers, who had settled in Nelson many years ago, had sent Home a sample of platinum, which had been found on the beach. He also stated that news of his brother's death reached them just as arrangements were being made to send out machinery to work the platinum deposits. Mr. Marmaduke Sellon, the younger brother referred to, died at Brightwater, 29th May, 1864, aged twenty-five years. The old Nelson provincial maps show that Sellon's run included within it a part of the Lee River. There appears, therefore, to be little doubt that the platinum which Mr. Marmaduke Sellon sent to London in the early "sixties" was found in the Lee River. His statement that it was found on the beach after a heavy flood suggested to his London friends that it was obtained on the sea-beach near the river-mouth. But in New Zealand miners apply that term to sandy deposits along the sides of rivers, and in all probability it was a river-beach that Mr. Marmaduke Sellon referred to.

Mr. John Sellon, Marmaduke's brother, sent me £20 to aid in prospecting. Mr. Hart and another miner were set to work. The sinking of a shaft on the lower end of one of the river-flats proved abortive; but some ground sluicing on one of the lower terraces—practically the river-bank—gave encouraging results. Seven hundred and forty-five grains of platiniferous sands were recovered, but much of this was chromite in a state of fine division. Most of the platinum was also in very fine flakes, but a few coarser pieces were recovered, the largest weighing nearly 4 grains.

The results of the ground sluicing were sent to London, and in reply Messrs. Johnson, Matthey, and Co. stated that one of their experts was visiting Australia, and that he had been instructed to call at Nelson *en route*. The expert came. He arrived late in December, 1913, and went straight to the Lee Valley. He was not favourably impressed. There was a fresh in the river at the time, which prevented prospecting the river-bed, but a few colours were obtained from material near the bank. He considered the flats too small and too shallow to warrant the expense of erecting an hydraulic sluicing and concentrating plant. He was, however, prepared to undertake and superintend more extensive prospecting on his return from Australia. Correspondence with the expert was maintained. On the 10th July, 1914, he wrote from Whyte River, Waratah, Tasmania, much regretting that his work there, for the time being, prevented his return to Nelson. Then came the outbreak of the Great War, and a hurried note from him to say that he had to return to England immediately.

Since that time some prospecting in a small way has been done, but nothing of much importance has eventuated. A little platinum has been found in the Roding River, and a colour or two in the Maitai.

If the expert had returned to Nelson as anticipated he would have explored not only the Lee Valley, but other parts of the Mineral Belt: so, from the point of view of possible mineral developments, the outbreak of war was a positive disadvantage to this district.

The writer's opinion is that the Mineral Belt still needs scientific prospecting. Chromite, copper, platinum, and a little gold have been found there, but hitherto not in payable quantities. There are enormous quantities of soft serpentine rock containing disseminated chromite. This rock could be excavated, crushed, and concentrated by modern machinery. The concentrates would contain some of all the above-named minerals, and perhaps others not yet discovered. But before entering upon such development works extensive prespecting would have to be carried out. Who is to provide for this prospecting? It would be fairly costly, and might prove the ground to be too poor to warrant heavy expenditure in construction of development works. On the other hand, a rich reward might await the prospectors. It is purely a speculative business on which few would care to venture. The born prospector, with shovel and dish, may yet find something to warrant expenditure in more extensive prospecting.

NOTES ON SOME STRIATED BOULDERS FOUND NEAR NELSON.*

By W. F. WORLEY.†

ON the Wakapuaka Road, just beyond the city boundary, there is a mixed boulder-gravel formation which in some earlier geological reports on this district was correlated with the Port Hills gravels. The two formations are, however, quite distinct, as proved by an examination of their constituent rocks. In the Port Hills gravels there is not a single stone which can be definitely identified as a Maitai rock, while in the boulder-gravels now under consideration every stone practically represents a well-known Maitai rock, even to the very characteristic banded Maitai slate. These boulder-gravels, though now steeply inclined with an easterly dip, and resting on a blue marine mud, are apparently an ancient delta of the Maitai River.

Large quantities of this mixed boulder-gravel material have been removed by quarrying in carrying out the reclamation of some of the adjacent mud-flats. Some of the boulders unearthed in these operations were enormously large in comparison with the rest of the deposits, and, being too heavy to be lifted on to the drays by which the filling-material was carted away, they have been left behind lying on the forefront of the quarry. Some of these large boulders are very distinctly striated, others faintly so.

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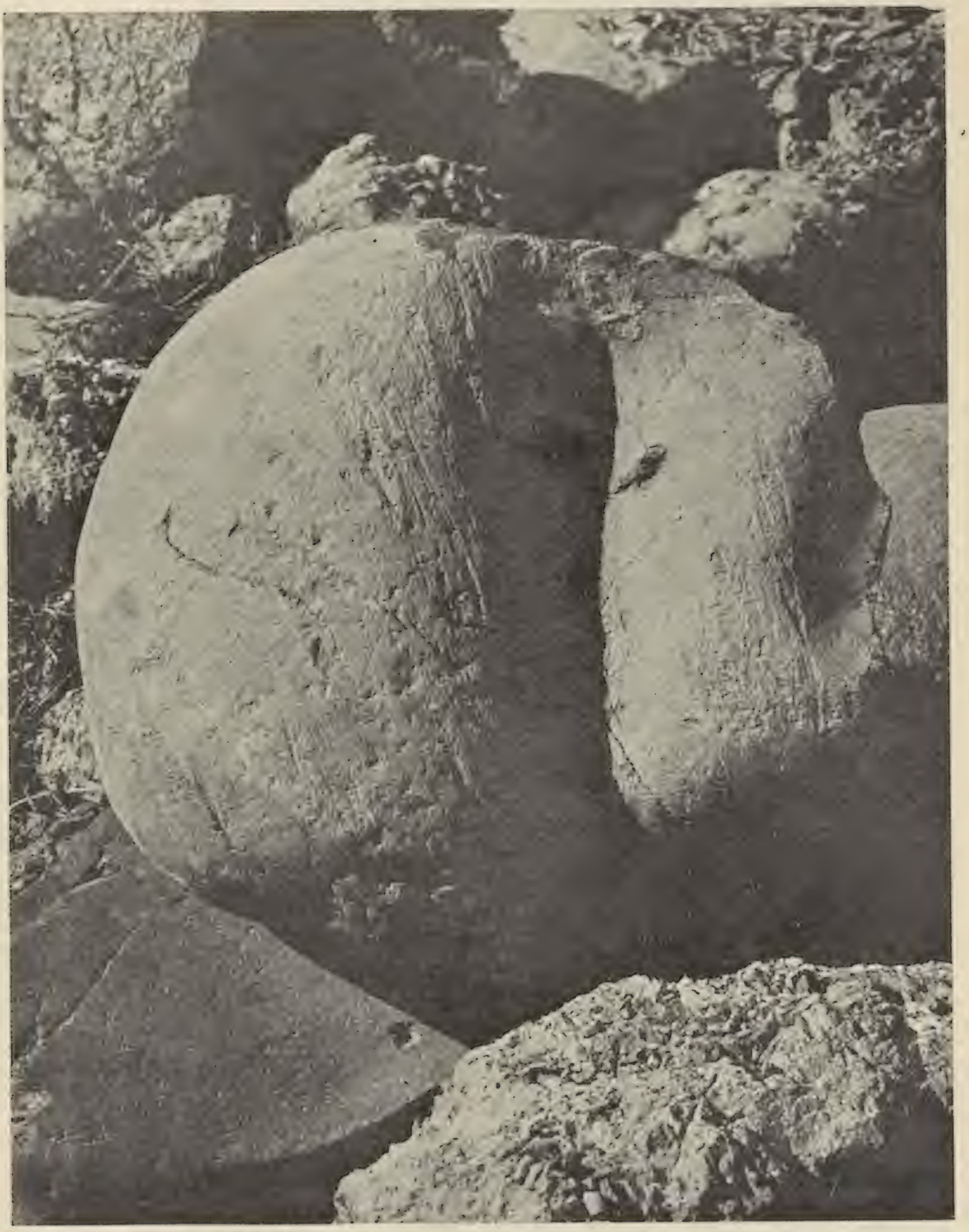
* A paper read before the Nelson Philosophical Society, 11th July, 1923.

† Mr. W. F. Worley died at Nelson, 4th August, 1923.

Though not able to accept—at least for the Maitai Valley—Professor Park's theory of extensive glaciation in Pleistocene times, the writer has long considered, with some degree of reservation, that these striated boulders, and some of the hill forms in the upper part of the Maitai Valley, are evidences of an earlier glaciation.



As the visit of a geologist is of rare occurrence in Nelson a local worker has not much opportunity of getting a second opinion on any geological problem. So last January the opportunity was seized of bringing these striated boulders under the notice of Sir Douglas Mawson, Dr. Marshall, and Mr. Bartrum, who were then on a flying visit to these parts. Unfortunately, they could not agree as to the probable cause of

the striations, and so there is still some doubt as to their origin. Sir Douglas Mawson considered they were due to glacial action, but Dr. Marshall and Mr. Bartrum could not support that view.

Three factors appear to be necessary to produce striations on rocks—namely, pressure, friction, and material of superior hardness to that showing the striations. Pressure and friction are always present in a mass of ice moving down a valley, but they may also occur by differential movement in a mass of boulder conglomerate, and boulders may become striated in that way. The possibility of this being the cause of the striations in the present case has been carefully considered, but had to be given up as untenable, as the remaining smaller boulders are perfectly waterworn and quite lacking in any angularity or sharp edges likely to produce scratches. Failing to find any other reasonable cause for the production of these striations, the writer has been forced to adopt a glacial theory as the most probable cause, and considers that in early Tertiary times the upper part of the Maitai Valley was glaciated. The presence of the striated boulders in the river-wash may be explained by making the reasonable assumption that ice blocks, carrying the boulders, were floated down the river in time of flood, and stranded on the river delta, where the boulders would remain after the melting of the ice.

The striations on the boulders are still quite distinct, but less so than they were when first seen some years ago. There is also a possibility that the boulders themselves will be removed, and that the evidence of probable glaciation which they supply will be lost. Hence the writing of these notes.

TARANAKI IRONSAND.

By W. DONOVAN, M.Sc., Dominion Laboratory, Wellington.

THE reported discovery in February last of the oxide of a new element in New Zealand ironsand by Dr. A. Scott, Director of Scientific Research in the British Museum, revived interest in the deposits of ironsand that fringe many parts of our coast. The sand examined came from Maketu, Bay of Plenty; and Dr. Scott, after further work, has now stated that the supposed new oxide is a refractory silicate of titanium; yet, in view of the interest aroused, the present time seems opportune for a summary from a chemical standpoint of our knowledge of the largest and best-known of the deposits, represented by the accumulation on the Taranaki coast, and hence called "Taranaki ironsand."

Mineralogically, Taranaki ironsand consists principally of magnetite (magnetic oxide of iron), ilmenite (titanate of iron), ferro-magnesian minerals such as augite and hornblende, some olivine, and quartz. Zircon is occasionally present. The magnetite and ilmenite do not occur as separate minerals, but are combined by intergrowth, and each magnetic particle contains both minerals.

From the chemical standpoint the most noticeable feature of the sand is the presence of about 10 per cent. of titanic oxide (TiO_2). This cannot be separated by mechanical or magnetic means from the iron oxides, and, owing to the restricted uses for titanium, has been regarded as so-much

worthless material, to be eliminated by fluxing if the sand is smelted for iron.

The chemical composition varies somewhat with the locality, but the following analyses may be regarded as representative, and illustrate the complex nature of the sand :—

	Patea Sand.	New Plymouth Sand.
Ferrous oxide	27·60	30·28
Ferric oxide	51·32	46·67
Manganous oxide	0·48	0·35
Titanium oxide	9·60	10·30
Alumina	1·04	1·62
Lime	1·25	0·62
Magnesia	2·60	2·80
Silica	5·30	6·20
Phosphoric anhydride	0·25	0·74
Sulphuric anhydride	0·04	0·03
Vanadium pentoxide	0·32	0·39
Water lost at 100° C.	0·20	Nil.
	100·00	100·00
Equivalent to metallic iron (per cent.) ..	57·39	56·22
,, phosphorus (per cent.) ..	0·11	0·32
,, sulphur (per cent.)	0·016	0·012

A trace of cobalt was observed by R. Smith, of the Royal School of Mines, London, in 1888.

A few crystals of zinc-blende have been noted in the sand near New Plymouth Breakwater.

The presence of vanadium was first proved in 1911. Messrs. Smith and Tweedale, of New Plymouth, claimed in 1912 the occurrence of valuable metals of the platinum group in the ironsand, but samples examined in the Dominion Laboratory did not contain more than 2 grains of such metals to the ton.

Approximately 0·1 per cent. of rare earths was detected in one sample analysed about 1913. These appeared to consist principally of ceria, the most common of the earths, and were not examined further.

Regarded as a source of iron, the sand, when concentrated to the highest possible degree by magnetic means, contains approximately 60 per cent. of metallic iron. The sulphur content is low. The phosphorus present is considerable, and though it is no detriment to the production of pig iron, its presence would necessitate the use of the basic process if the manufacture of steel were attempted.

The titanium dioxide represents to the iron-smelter so-much worthless material that cannot be eliminated by mechanical means, and must be removed by fluxing in the furnace. There is also a prejudice against it, as it is said to render the slag somewhat pasty. Rossi, however, was able to produce quite fluid slags with the ordinary fluxes, and, by the substitution of dolomite for part of the limestone in the furnace charge, obtained a lime-magnesia titanium slag of marked fluidity.*

The chief obstacle, however, to the successful treatment of the iron-sand in a blast furnace is not its chemical composition but its physical condition. It is a very fine sand, practically all of which passes a 40-mesh sieve, and must be agglomerated before being fed into the furnace. A cheap and satisfactory means of so doing has yet to be found.

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* *Trans. Am. Inst. Min. Eng.*, vol. 21, 1893, pp. 832–64.

A concise summary of attempts to manufacture iron from the sand on a commercial scale is given by Clark in *N.Z. Geological Survey Bulletin No. 14* (new series), pp. 48–51.

A description of the most recent effort was published in the *Transactions of the American Institute of Mining and Metallurgical Engineers*, No. 162, 1920, by J. A. Heskett, in a paper entitled "Utilization of Titaniferous Iron-ore." It is a valuable contribution to the study of Taranaki ironsand.

Heskett first briquetted the sand by mixing it intimately with a strongly coking coal, in the proportions of 1 to 1, and coking in an oven. The ferro-coke was charged into a small blast furnace with the required amount of limestone. Cold blast was used. The reduction of the ore to metal was satisfactory, and about 10 tons per day were produced of a close-grained iron of analysis—Graphitic carbon, 2·82 per cent.; combined carbon, 0·75 per cent.; silicon, 0·91 per cent.; manganese, 0·42 per cent.; phosphorus, 0·56 per cent.; sulphur, 0·04 per cent.; titanium, 0·28 per cent. But, owing to the disintegration of the ferro-coke, fine particles of coke became entrapped in the slag, and this process was abandoned.

A mixture of one part of coal with three of sand was next tried, with the addition of a weak solution of sodium silicate. The mixture was briquetted, coked as before, and charged into the furnace with additional coke and limestone. The slag was good, but the iron was low in silicon. The fuel-consumption was high.

Sintering the ironsand instead of briquetting with coal led to imperfect reduction in the furnace, and a hard steely pig iron. Briquetting was again reverted to, with one part of coal to eight of sand, the materials being finely ground together in a mill. A hot blast was also installed. The furnace was charged as usual with briquettes, coke, and limestone. The slag was fluid, and the pig iron satisfactory. But accretions, consisting of a mixture of ferro-titanium and cinder-like slag containing over 40 per cent. of TiO_2, accumulated on the hearth, and eventually blocked the furnace. It was evident that the non-ferrous constituents of the ore had sintered together, forming a product of high specific gravity, which had sunk through the charge without coming into sufficiently intimate contact with the limestone to be fluxed.

As a remedy, Heskett suggested grinding limestone, coal, and ironsand together so as to produce a self-fluxing briquette. The work, however, was discontinued at this stage, for commercial reasons.

It had been clearly demonstrated that slags with 10 and even 20 per cent. of TiO_2 were quite fusible and gave no trouble in the furnace, and that pig iron of good quality could be produced from the ironsand.

The following are analyses of some of the slag and pig iron:—

Slag.

	Heskett.	Dominion Laboratory.
Silica (SiO_2)	30·70	32·40
Alumina (Al_2O_3)	17·60	15·17
Manganous oxide (MnO)	0·50	*
Ferrous oxide (FeO)	1·00	1·15
Lime (CaO)	31·20	35·80
Magnesia (MgO)	4·10	6·36
Alkalis ($K_2O.Na_2O$)	2·60	2·03
Titanium dioxide (TiO_2)	10·20	7·09
Sulphur	1·20	*
	99·10	100·00

* Undetermined.

Pig Iron.

	Heskett.	Dominion Laboratory.	
		(1.)	(2.)
Graphitic carbon	2·89	2·56	0·13
Combined carbon	0·70	1·09	2·66
Silicon	1·60	1·04	*
Manganese	0·45	0·30	0·18
Sulphur	0·06	0·01	Nil.
Phosphorus	0·51	0·36	0·42
Titanium	0·63	0·40	0·55

* Undetermined.

Heskett notes that the iron had a tendency to chill, and was more adapted to steel-production than for use as everyday foundry iron.

The analyses made in the Dominion Laboratory indicate low silicon, high combined carbon, and, in case of No. 2 sample, a product of extreme hardness.

While there is no doubt that the technical difficulties of blast-furnace treatment of the ironsand could be overcome, there is equally no doubt that it could not compete at the present time with iron-production from solid ore.

There remains, however, one possibility of treatment that is worth consideration. If a process could be devised which would not only produce iron from the sand, but also at the same time render the titanium content available for use commercially, some margin of profit might remain.

Ferro-titanium is widely used for treating steel intended for rails. Titanium compounds are used in dyeing leather, and are often constituents of pottery-glazes. Titanium dioxide is white in colour, and is an exceptionally good pigment. It is non-poisonous, has considerably greater covering-power than white-lead, and, should the use of the latter be prohibited at any time for hygienic reasons, would be in strong demand.

In considering the treatment of titaniferous iron-ore Goodwin has recently pointed out that titanium dioxide can act either as an acid or a base. The practise hitherto has been to regard it as an acid, and to add basic fluxes, as lime and magnesia, producing titanates of lime and magnesia in the slag. Regarding it, however, as a base, he suggested combining it with the acid silica; and apparently has succeeded in producing a fusible slag consisting mainly of silicates of titanium and alumina. The paper, of which only a brief abstract was available, was published in the *Transactions of the Royal Canadian Institute*, No. 13, pp. 35–49 (1921).

A process such as this would reduce considerably the amount of flux to be added, and also the quantity of slag produced.

The cinder which blocked the furnace in Heskett's last experiments was essentially a silicate of titanium. It would seem possible, therefore, that if the ironsand, reducer, and siliceous flux were intimately mixed in the correct proportions, and subjected to heat in an electric furnace which would attain a sufficiently high temperature and obviate the use of a blast, not only would pig iron be produced, but a slag rich in titanium would result. Such a slag might be used as a source of titanium compounds. Electric current would need to be cheap, for from 2,000 to 2,500 B.T.U. would be required for every ton of iron obtained. Experimental work would be necessary before a satisfactory estimate of the cost of such a process or of the value of the products could be given.

Some work on the extraction of vanadium from the sand is also desirable.

The writer is convinced that the recovery and utilization of by-products are essential factors in the manufacture of iron from Taranaki ironsand.

THE INDIGENOUS GRASSES OF MOUNT HERBERT, BANKS PENINSULA, AND ITS NEIGHBOURHOOD.

By Professor ARNOLD WALL, Canterbury College, Christchurch.

General Description.

MOUNT HERBERT, the main peak of which is 3,012 ft. high, is the highest point on Banks Peninsula. Most of its surface is now tussock-grassland. Fallen logs show that forest formerly grew in certain places at the heads of the valleys and near the summit where grass now grows, but the northern and eastern faces and spurs have apparently always been clear of bush in recent times, while at the bottom of the valleys small bush grew, and is still represented by remnants. The basins at the head of the streams running into Purau, Charteris Bay, and Kaituna valleys have all held large areas of mixed forest, predominantly of totara; the Purau and Charteris Bay forests have mostly been destroyed, but the area at the head of Kaituna Valley is still large and imposing. This forest runs up to within 200 ft. or 300 ft. of the summit, where it ceases upon reaching a tier of very steep rocks. Upon and about these rocks there is a considerable remnant of a belt of subalpine scrub, consisting mainly of *Veronica buxifolia*, *V. leiophylla*, *V. salicifolia*, *Olearia nummularifolia*, *O. Forsteri* var., *Leptospermum ericoides*, *Phormium tenax*, and *Dracophyllum uniflorum*.

Facing south and west, these damp rocks, with their accompanying forest immediately below and scrub above, form the best locality on Banks Peninsula for subalpine species, and the majority of the rarer indigenous grasses here dealt with have been discovered in this place.

With the exception of these large areas of forest, and of smaller areas in the Charteris Bay and Port Levy valleys, the mountain presents the usual facies of Canterbury tussock-land, the great masses of *Poa caespitosa* and *Festuca novae-zelandiae* giving the long spurs and level-topped ridges the predominantly tawny colour which is so characteristic of the grass-lands of the South Island on the eastern side. Close examination, however, shows that a large number of less conspicuous species of introduced and indigenous grasses occupy the ground between the larger tussocks, and these, rather than the *Poa* and *Festuca*, *Agropyrum scabrum* and *Dichelachne crinita*, supply the most valuable part of the pasture.

Zones.

Mount Herbert is not high enough to admit of any very important variation in the composition of the grass-flora according to altitude. The extreme summit is level and thickly grassed, and *Alchemilla arvensis* is more abundant there than elsewhere on the mountain. The lower slopes, up to about 500 ft. or 1,000 ft., have long been cultivated and sown down in introduced grasses and *Danthonia semiannularis*. It is therefore hardly possible to tell what was their original state, but the occurrence of *Raoulia Monroi* and *Carex resectans* upon the rockier portions up to about 1,000 ft. shows that these slopes must have been very dry, and it seems certain that their vegetation agreed closely with that of the Port Hills and

Canterbury Plains, since these two species are definitely confined to very dry areas, such as the plains of Central Otago and Canterbury. From about 1,000 ft. upwards there is little change perceptible in the character of the grassland, but naturally the damper southern and western faces, the shaded rocks, and the edges of such bush as remains in the gullies give shelter to such grasses as *Asperella gracilis* and *Deyeuxia Petriei*, while *Danthonia nuda* will be found only in exposed and comparatively dry situations. It is obvious that the present state of the mountain in these respects is very different from the natural—constant burning and pasturing must have profoundly altered the original associations; but, although many species of flowering-plants have possibly disappeared altogether (*e.g.*, *Bulbinella Hookeri*), it is hardly likely that many species of grass have been actually displaced. The balance of the species must have changed much; the spread of *Danthonia semiannularis* here, as on the neighbouring Port Hills, is an indication of this.

VALUE AS PASTURE.

The grassy slopes of Mount Herbert, especially those facing north and west, offer exceedingly rich and abundant pasture. The late Mr. Laurence Wilson, of Teddington, who held the western portion of the mountain (Castle Peak), informed the writer that he could carry five sheep to the acre on the higher parts of his country all the year round in an ordinary season. Even in very dry seasons fog and dew seem to keep the grasses comparatively fresh and healthy all over the higher slopes. Tussocks of *Poa caespitosa* over 3 ft. in height and most luxuriantly tufted are not uncommon in some parts.

Undoubtedly, however, the chief value of this pasture lies in the introduced rather than in the indigenous grasses. Of these the most abundant are *Anthoxanthum odoratum*, *Holcus lanatus*, *Dactylis glomerata*, *Agrostis stolonifera*, and *Lolium perenne*, all of which occur at all altitudes and in nearly all situations. Observation shows that these are what the stock chiefly eat: the tussocks are left untouched; even *Poa Colensoi* is hardly eaten at all. The spaces between the tussocks are generally eaten quite short, and the plants which are found most palatable by sheep are the small clovers, *Hypochaeris radicata*, and the grasses above named. It is remarkable that the sheep in general prefer to feed in places where the rocks come close to the surface and the vegetation is comparatively short and fine, rather than upon the steeper slopes clad with the very rank growth of the larger grasses.

Some of the holders of the country have been consulted on this aspect of the subject; they agree that Mr. Wilson's estimate was much too high. Mr. Orton Bradley, of Charteris Bay, says that one and a half sheep to the acre is the utmost capacity of his country.

LIST OF GRASSES.

The following is the list of grasses hitherto observed on Mount Herbert and in its neighbourhood :—

1. *Microlaena avenacea* Hook. f. (forest rice-grass). In forest only.
2. *Microlaena polynoda* Hook. f. (knotted rice-grass). In dry forest and occasionally at the base of rocks.
3. *Hierochloe redolens* R. Br. (holy-grass). Abundant throughout, especially in damp situations.

4. *Echinopogon ovatus* Beauv. (rough-bearded grass). On dry slopes only, generally at the base of rocks.
5. *Agrostis parviflora* R. Br. (small-flowered bent-grass). Discovered recently on the edge of the forest and below shaded rocks close to the summit, at about 2,800 ft., on the south and south-west sides; also at the head of the Purau Valley at about 2,500 ft.
6. *Deyeuxia Forsteri* Kunth. Abundant throughout at all elevations. In some spots, near the Southern Peak especially, it attains a height of 3 ft., growing very strongly and luxuriantly.
7. *Deyeuxia avenoides* Buch. (the type) and (8) var. *brachyantha* Hack. both occur. The typical but rarer form with large spikelets occurs on the edge of the bush near the summit on the south and west sides; the var. *brachyantha* is not uncommon from about 2,000 ft. upwards, and is more generally distributed.
9. *Deyeuxia Petriei* Hack. Fairly abundant all over the south and west slopes between the bush-line and the summit, at about 2,800 ft.; also at the head of Charteris Bay.
10. *Dichelachne crinita* Hook. f. (plume-grass). Abundant, especially on the lower slopes, and even quite close to the sea.
11. *Trisetum antarcticum* Trin. Fairly common on the south and west sides just within or just above the forest or scrub at about 2,800 ft.; also in the gullies at the head of the Purau Valley.
12. *Danthonia Cunninghamii* Hook. f. (Cunningham's snow-grass). Abundant on the south and west faces near the summit, and in similar situations at the head of the Purau Valley.
13. *Danthonia Raoulii* Steud. (snow-grass). Occurs (but sparingly) above 1,800 ft.; is also on the Port Hills, but rare.
14. *Danthonia pilosa* R. Br. (purple-awned oat-grass). A regular constituent of the pasture, but less abundant than the next species.
15. *Danthonia semiannularis* R. Br. (common oat-grass). Abundant throughout and at all elevations, and an important element in the pasture.
16. *Danthonia semiannularis* var. *setifolia* Hook. f. Not uncommon on and near dry rocks facing north and north-west, especially on Mount Evans, on the south side of the Purau Valley, at about 2,000 ft. and upwards.
17. *Danthonia semiannularis* var. *nigricans* Petrie. On the south and west sides near the summit; not common.
18. *Danthonia nuda* Hook. f. = *Triodia Thomsoni* (J. Buchanan) Petrie. Most abundant on level-topped spurs at about 1,500 ft. to 2,000 ft., especially on the northern and north-eastern sides.
19. *Arundo conspicua* Forst. (toe-toe). Not uncommon, especially in damp situations throughout.
20. *Koeleria Kurtzii* Hack. On the south and west sides, above the forest and about the summit, from 2,500 ft. upwards.
21. *Poa caespitosa* Forst. (silver-tussock). Abundant throughout.
22. *Poa anceps* Forst. (common field poa). Mount Herbert, 2,800 ft., south and west sides.
23. *Poa Colensoi* Hook. f. (blue-tussock). Abundant from about 1,500 ft. upwards on the sunny faces and level spurs.

24. *Poa Kirkii* Buch. (Kirk's poa). Hitherto only observed in one spot on a small outcrop of rock close to the summit on the south-west side, and by no means abundant in that place.
25. *Poa imbecilla* Forst. (weak poa). In forest and at the base of shaded rocks; abundant.
26. *Festuca ovina* Linn. var. *novae-zelandiae* Hack. (New Zealand sheep's fescue). One of the dominant grasses from sea-level to the summit.
27. *Festuca rubra* Linn. (red fescue). Not as yet certainly identified, but probably present in one or other of its numerous forms.
28. *Festuca* sp. undescribed. On rocks near the summit, on the south and west sides, but not on the dampest places; fairly abundant.
29. *Agropyrum scabrum* Beauv. (blue-grass). Abundant throughout.
30. *Asperella gracilis* (Hook. f.) T. Kirk. Edge of forest or scrub and in damp open gullies on all sides of the mountain at 2,000 ft. upwards.

Of the above species those which are recorded from the south and west slopes of Mount Herbert, near the summit, doubtless occur also (some of them, at any rate) in similar localities, such as the heads of the Purau, Port Levy, and Charteris Bay valleys, most of which places have not been so thoroughly examined as yet.

I must express my great obligation to Mr. Petrie for his valuable assistance in the preparation of this paper. He has most kindly identified the various grasses here collected as they were sent to him from time to time, and also read through the paper, furnishing me with indispensable details, especially on terminology, which I could not possibly have obtained otherwise.

NOTES ON THE CHEMISTRY OF THE NEW ZEALAND FLORA.

By ROY GARDNER, M.Sc., F.C.S.

THE flora of New Zealand is, botanically, one of the most varied and interesting in the world, and there can be no doubt that its plants contain many substances of chemical interest, and perhaps also of pharmacological or technical importance. Up to the present, however, the chemical aspect of the flora has received little attention, with the noteworthy exception of the excellent work of Professor Easterfield and his collaborators. New Zealand is, in this respect, a long way behind Australia, but at the present time considerable interest is being taken in the subject, and a fair amount of work is under way.

These notes are intended to present a brief summary of the present state of our knowledge in this subject, incorporating a few hitherto unpublished results, especially on the essential oils. The appended list of references is probably incomplete, but will at least serve as a nucleus.

In connection with possible discoveries of pharmacological value it is of interest to note that the flora has already provided quite a compre-

hensive materia medica, many medicinal plants having been known and used by the Maori. Their knowledge was to some extent inherited by the colonists, and fragments of it are to be found in bush camps and back-block homesteads to this day. In dealing with Maori medical lore it must be difficult to separate physiological from psychological effect, but Dr. Goldie has left a list—probably far from complete—of plants known by the Maori to be of medicinal use. It is sincerely to be hoped that other persons who are in possession of parts of this fast-dying lore will place it on record. Such information has not only an ethnological value, but may serve as a guide in chemical investigation also.

ESSENTIAL OILS.

Up to two years ago practically no chemical work had been done on these, although a number were known to exist. Their chemical examination is now being carried out, and some interesting results are already available.

In the pine group Mr. B. H. Goudie has examined the leaves of the cedar (*Libocedrus Bidwillii*), which contain 0·5 per cent. of an essential oil containing terpenes—chiefly pinene, and a sesquiterpene which is probably cedrene ; and the same investigator finds that the leaves of rimu (*Dacrydium biforme*) give 0·25 per cent. of oil containing terpene, sesquiterpene, a solid diterpene (one of the few known), and an unidentified oxygen compound. The leaves of *Phyllocladus* also give an oil, which has not yet been fully investigated.

Among the higher flowering-plants, our oil-bearers include members of both suborders of the important essential-oil order *Myrtaceae*. Our true myrtles (including ramarama) have not been investigated, although it would be interesting to know how their oils compare with those of the European myrtles. In the suborder Leptospermeae, which includes the eucalypts, we have two genera—the manukas (*Leptospermum*) and the ratas (*Metrosideros*).

The essential oils of both species of manuka have been examined, and it is possible that the results will have a botanical as well as a chemical significance. The monumental researches of Smith and Baker have shown without doubt that in the case of the eucalypts, lines of evolution can be laid down from the evidence afforded by the composition of the oils ; and it may well happen that when more of the Australian species have been examined it will be possible to do the same with the leptosperms and so settle the vexed question of the relationship between the two New Zealand species.

The oil of the endemic species, *Leptospermum ericoides*, has been examined by Short and Johnston at Auckland University College, and in a communication to the Wellington meeting of the Australasian Association they give the composition as—Pinene, 76·6 per cent. ; the sesquiterpene aromadendrene, 9·5 per cent. ; the phenol tasmonol, 2·5 per cent. ; terpineol, 2 per cent. ; and traces of terpenyl acetate and of citral.

Leptospermum scoparium oil has been examined by the present writer. The oil consists chiefly of a sesquiterpene which is probably aromadendrene, with some high-boiling oxygen compounds not yet fully investigated, $2\frac{1}{2}$ per cent. of a phenol which is probably identical with leptospermol from one of the other Australian species, a small quantity of terpene, and some esters. The esters include the acetic and butyric esters of a terpene alcohol, and, curiously enough, esters of cinnamic acid. These cinnamic

esters, in the possession of which this species seems to be peculiar amongst the leptosperms, are present in very small quantity (not much more than 1 per cent.), yet their cinnamon-like odour is often noticeable in the manuka scrub on a bright sunny day. This investigation is being continued.

In the rata genus Mr. G. M. Moir finds that *Metrosideros lucida* gives about 0·3 per cent. of oil, which is being further investigated.

Mr. F. H. McDowall is examining the leaves of the ngaio (*Myoporum laetum*), and finds that the prominent glands yield a variable quantity of an essential oil, which is being investigated further. Mannitol is also present in the leaves.

Mr. Moir has obtained from *Olearia illicifolia* a small quantity of essential oil, having the characteristic odour of the leaves.

Fixed Oils.

The seeds of the native flax (*Phormium tenax*) contain about 20 per cent. of their weight of oil. Of other fixed oils one might mention that of the seeds of *Passiflora tetrandra*, which was used by the Maori as a remedy for chronic sores, and that of karaka-seeds (see under "Glucosides").

Tannins.

Our flora is rich in tannins, and, although little chemical work has been done on them—and the tannins are, chemically, a somewhat obscure group—their commercial value (potentially, at all events) has been recognized. In one case (*Phyllocladus*) the bark has been exported for tanning purposes.

On the pharmacological side, the value of many of the bushman's remedies, such as the barks of the ratas, kauri, and manuka, probably consist chiefly in their astringency, due to tannin. The best-known of these astringents is the leaf of koromiko (*Veronica salicifolia*), of which a tincture appears in the *Extra Pharmacopoeia*, where it is described as being "used in New Zealand and China." Reasons (of somewhat doubtful validity) have been adduced for believing that the medicinal virtues of this plant are not wholly due to tannin, and the point is now being investigated.

Resins.

In this group work has been done by Easterfield and his collaborators on the *Podocarpus* resins (totara, rimu, &c.), and podocarpic acid has been isolated. The same investigators obtained a tertiary alcohol, totarol ($C_{20}H_{30}O$), and other substances, from totara sawdust.

Kauri-resin and its distillation products, in view of their commercial importance, deserve more attention than they have had. Probably a good deal of work on this subject is unpublished.

Gums.

We have a number of what are broadly described as "gums," but probably most of them are gum-resins or oleo-resins.

Those from miro (*Podocarpus ferruginea*) and a rangiora (*Brachyglottis repanda*) have been used for their healing properties, although the leaves of the latter plant are said to be poisonous, and the gummy exudation from the spaniard (*Aciphylla*) was one of the Maori perfumes.

Melicope ternata (wharangi) belongs to the Rutaceae, and it is not surprising that its gum should have medicinal properties. The leaves (*cf.* buchu) may also be worth investigating. Goldie mentions that the

Melicope gum is to be distinguished carefully from that of *Olearia Cunninghamii* (wharangapiro), which is a deadly poison. The danger of confusion probably lies between the names rather than between the plants, and, to make matters worse, *Brachyglottis repanda* seems also to be known as "wharangi" in some places.

The true gum of the flax-leaf is described by Church, who mentions that it is alkaline. Its medicinal value is much contested, some bushmen contending that it has valuable healing properties, while others, including flax-mill workers, say that it is poisonous and causes festering. The question is probably bacteriological.

GLUCOSIDES.

Probably the most interesting substances yet obtained from our flora are the two poisonous glucosides, worked on by Skey, and afterwards by Professor Easterfield and Mr. B. C. Aston.

The poisonous properties of the tutu-plant (*Coriaria ruscifolia*) are well known—only too well known to many live-stock owners—and there have been a number of cases of Europeans being poisoned by it. The active poisonous substance is a glucoside, isolated and named "tutin" by Easterfield and Aston in 1900. It is accompanied in the plant by acetic, succinic, gallic, and ellagic acid, and its formula is $C_{17}H_{20}O_7$. The physiological action, which is described as allied to that of picrotoxin, has been investigated by Dr. Malcolm, of Otago University, who, however, does not hold out any hope of therapeutic value. Notwithstanding the poisonous nature of the plant, Goldie states that a decoction of the leaves was used by the Maori as a medicine, and the juice of the pith was an ingredient of a mixture for insanity!

The other poisonous glucoside is karakin, from karaka "berries" (*Corynocarpus laevigata*). This fruit is poisonous in the raw state, but the Maori used it as a staple food after soaking and boiling, which treatment evidently hydrolysed the glucoside. The aqueous extract gives much hydrocyanic acid on distillation, so that the glucoside appears to be one of the cyanogenetic group. It can be extracted with cold alcohol, and has the formula $(C_5H_8NO_5)_3$. The berries contain also sugars (mannose and dextrose), and 14 to 15 per cent. of a non-drying oil, giving solid acids on saponification.

ALKALOIDS.

No members of this group have yet been reported, although some of the chief alkaloid-bearing families are represented—for instance, the Loganiaceae by *Geniostoma* and the Rubiaceae by the numerous coprosmas. *Solanum aviculare* ("bulli-bull") has been examined for alkaloids by Mr. Finlay, but none were found.

UNCLASSIFIED BITTER PRINCIPLES.

Under this heading the cathartic substances of flax-root may be mentioned. Many of our plants contain bitter substances which call for further investigation.

The bark of kohekohe (*Dysoxylon spectabile*) contains a bitter substance which Goldie describes as "allied to quinine," presumably meaning allied in physiological action. This point will be investigated in the near future.

"HOT" PRINCIPLES.

Of the two plants which furnish "bush painkiller," one, *Macropiper excelsum*, is a true pepper, and probably not much different chemically from other members of the family. The other, the horopito or pepper-wood (*Drimys axillaris*), is a member of the Magnoliaceae, being a sister plant to the South American *Drimys Winteri*, source of the once important but now almost forgotten medicine Winter's bark. Mr. H. J. Finlay considers the hot principle to be resinoid in character, but was unable to isolate it. He also found that the leaves contain a small quantity of essential oil (terpene and sesquiterpene) and about 8 per cent. of tannin.

Doubtless there are many plants not mentioned in this paper which would be worth chemical research. It is hoped, however, that enough has been said to give some idea of a wide, interesting, and important field of work which calls for systematic investigation.

I am greatly indebted to Dr. Inglis, of Otago University, and to my colleagues in his laboratory, Messrs. Finlay, McDowall, Goudie, and Moir, for permission to quote results not yet published.

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WORDS AND RACES.

Story of the Kumara.

By F. W. CHRISTIAN, B.A. (Balliol College, Oxford), and Corresponding Member of the Polynesian Society of New Zealand.

Kumara, the musically sounding name given by the Maori to the sweet potato—in various dialect forms *kumala*, *umala*, *umara*, *kuara*, *uala*—is widely spread all over the great Pacific, from Hawaii down to New Zealand, from Samoa and the 180th meridian down to the Low Archipelago and its farthest eastern edge. Maori traditions and genealogies, as Mr. Elsdon Best can tell us, have preserved the very name of the adventurous sea captain who brought this tuber into the central Pacific basin from Hawaiki. From these family records we can obtain a fairly approximate date of its introduction, and from the evidence now at the disposal of scientists we have almost as clear historical testimony as to its coming as that contained in the account given us by Elizabethan chroniclers of the introduction of the potato from America into England by Sir Walter Raleigh.

Connected with the widespread name of this tuber are two questions of fascinating interest: (1) The origin of the forefathers of the Maori from the Indian Archipelago, where the tuber is known under a closely related name; (2) the probable discovery of South America by early mediaeval Indonesian sea captains belonging to the same migration, who, bolder than their fellows, pressed on past Hawaii and Hawaiki, following the mighty eastward drift of the northern equatorial counter-current.

Let us look at the evidence, which is curious and interesting. The original home of the *kumara* was certainly the great tropical island of Java, where vast plantations of it have been cultivated for centuries untold, the Malay name for the root being the *ubi-Java*, or the *yam* of Java. From Java it spread all over the Malay Archipelago right across the Philippines. All these Indian Archipelago names for the *kumara* answer to a set of names given in the Sanskrit, or the ancient language of India, to the blue, the white, and the red edible lotus-lily, which has a sweetish floury tuber, and which for generations has been cultivated along the Ganges, together with the *taro* and the *yam* (both of which have Oceanic and South American names).

The Sanskrit names fall under four headings: (1) *Kumad*, *kumal*, the white lotus; (2) *kumud*, the white lotus; (3) *kamal*, the red lotus; (4) *kuvara*, *kuvala*, *kuvera*, the blue edible lotus (Mangaia, Cook Islands, *kuara*, *kuawara*, the sweet potato; Hawaiian Islands, *uala*, *iwala*). We need not be astonished to find these and hundreds of other Indian names in Java, seeing that history tells us plainly that, about the beginning of the Christian era, vast numbers of colonists from India began to flock across to the beautiful and fertile island in great teak-built vessels fitted with giant outriggers, such as we see sculptured in stone to this very day on the south façade of the Borobodo Temple in south Java. Java thus became a Hindu colony, ruled by Brahmin princes, and, being almost as much a part of India as the Isle of Wight is of Hampshire, profoundly influenced the mixed people of the Malay Archipelago and more or less Hinduized them from end to end.

With the first-mentioned Sanskrit forms, *kumad* and *kumal*, we may certainly identify the Polynesian forms *kumara*, *kumala*, and the harsher Javanese form *kumadjang*. With the second Sanskrit form, *kumad*, we

may safely compare the Philippine Island form *comote* and *kamote*, and the Mariana Islands word *camute*, or *kamute*, for the sweet potato. The Mexican name is *camotli*—whether borrowed or not I cannot tell. With *kamal*, the Sanskrit word applied to the red lotus, may be compared *kamal*, the name of the *kumara* in the peculiar language of Ruk, in the Central Carolines, 1,200 miles north of New Guinea. There the great current rushing north-westward past the Papuan coast takes an abrupt bend, and pours like a mighty salt-water river due eastward about 15° north of the Line, setting straight for the Hawaiian Islands, and onward to the South American sea-board, which it laps just below Panama, and flows then due past the Esmeralda coast and down to the Gulf of Guayaquil. And now comes a very astonishing fact. In the red men's language of Ecuador the white potato is called *cumar*, or *kumar*, and, according to the vocabularies of Dr. Middendorff and Sir Clements Markham, the Aymara or Colla Indians of upper Peru also know this tuber as *cumar*.

The conclusion seems fairly obvious that the main body of this great immigration outwards from teeming Indonesia stayed in Hawaiiki or the Hawaiian Islands, and then, in a curving course, swept southwards to Tahiti and the Cook Islands, finally reaching New Zealand, and that others more enterprising pushed right on to the shores of the great continent and settled there. Two Peruvian traditions recorded by Sir Clements Markham are interestingly illustrative :—

(1.) The Chimu, or Chamorr, a civilized folk formerly occupying the coast of northern Peru, and still surviving around Payta and Eten, state that they were descended from a band of warrior emigrants who came from overseas and landed at Guayaquil, just below Quito, a place which is the best natural harbour to be found all along the Pacific coast of South America.

(2.) The Incas speak of a mythic civilizer (Bira-Cocha—" Sea Foam ") who came from over the sea, and declare, moreover, that the Prince Manco Capak (Manco* is a Javanese princely title) was the founder of a new Inca dynasty about 320 years before the Spanish conquest of Peru by Pizarro.

Not to weary the reader with technical details, I may state that I have discovered abundant evidence in names of metals, ceramics, textiles, colour-names, and ordinary names of things in the Inca language of Peru, and the red men's language of Arauco in south Chile, which clearly enough shows that these peoples have been crossed by Indonesian immigrants of a high type. Two more tuber-names will suffice as additional evidence of this : *Cachu*, or *kachu*, is the Inca name for the common potato, and in Sanskrit *kachu*, or *kachhu*, is the name for the *taro* or edible arum cultivated in the Ganges Valley, and to-day it is the common name for the " potato " in India.

Gandu and *gaddu* are the Sanskrit names for " bulb," " tuber " ; also for the *yam* in ancient India. *Gado* in the Philippine and Mariana Islands also means *yam*. According to my friend the late Canon Codrington, that great scholar of Melanesian languages, *gadu* is a common word for the *yam* in that area. Lastly, in the language of those valiant red men, the Indians of Arauco, in south Chile, who defied Valdivia and the Spanish yoke so successfully—a language crossed by dozens of Polynesian words—the *yam* is called *gaddu* here also.

Such evidence as I have given above is what jurists and philologists call " cumulative." It is altogether out of the question to suppose these widespread and mutually illuminating root-names to be due to accident and chance, and it now rests with students of this particular line of research to follow up the trail.

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* *Cf.* the Javanese royal titles *Mangkoe Buni* and *Mangkoe Negara*. Cf. *The Statesman's Year-book*, p. 1091 (1920) (Netherlands – East Indies).

ASEROE RUBRA, AN INTERESTING NEW ZEALAND PHALLOID.

By G. H. CUNNINGHAM, Biological Laboratory, Wellington.

THIS fungus is common throughout New Zealand, and may at certain seasons of the year be obtained growing amongst decaying leaves on the forest-floor. It is readily noticeable owing to its bright-red colour, superficial resemblance to a sea-anemone, and penetrating odour. When in the forest one frequently becomes aware of its presence, owing to its powerful odour, before the plant itself is observed. As will be shown below, the bright colour and penetrating odour are factors that play an important part in spore-dissemination.

ASEROE La Billardière.

Relation du Voyage a la Recherche de La Perouse, 1791 and 1792. Paris arr. viii de la rep., p. 145, 1799–1800.

Volva at first globose, becoming cupulate, composed of three layers, exo-, meso-, and endo-peridium; attached to the substratum by numerous white rhizoids. *Stipe* at base enclosed in the volva, becoming broadly expanded at apex. *Receptacle* borne at apex of stipe, expanded into a horizontal disc, the margin of which is divided into a variable number of rays. *Gleba* gelatinous, coloured, fetid, imposed on upper surface of disc and proximal part of rays. *Spores* continuous, coloured.

Distribution.—The genus occurs in Australia, Japan, China, Ceylon, Java, Brazil, and is in New Zealand represented by the following single species.

Aseroe rubra La Billardière, *l.c.*, p. 145.

Aseroe pentactina Endlich., *Icon. Gen. Plant.*, pl. i, 1838. *A. viridis* Berk. et Hook. f. in *Hook. Jour. Bot.*, vol. 3, p. 192, 1844. *A. actinobola* Cda., *Icon. Fung.*, vol. 6, p. 23, 1854. *A. Hookeri* Berk., *Fl. N.Z.*, vol. 2, p. 187, 1855. *A. corrugata* Col., *Trans. N.Z. Inst.*, vol. 16, p. 362, 1883. *A. Muelleriana* Ed. Fisch. in *Sacc. Syll.*, vol. 7, p. 26, 1888.

Volva at first obovate, becoming at maturity cupulate, up to 3 cm. diam., consisting of three layers, a dingy-white exoperidium, a gelatinous thick mesoperidium, and a delicate hyaline endoperidium; attached to substratum by a few coarse white basal rhizoids. *Stipe* cylindrical, at base enclosed in volva, white, shading to pink towards apex, up to 6 cm. high and 2 cm. wide, variable in size, obconic, hollow, pervious at the apex, cellular, somewhat rugulose, subtranslucent, expanding at the apex into a broad circular disc-like receptacle up to 3 cm. wide, to which are attached the rays. *Rays* 5–8, red, conniving, up to 3·5 cm. long, 6 mm. wide, at the base longitudinally grooved, rugose on both surfaces but more deeply on the upper, bifurcate at about 15 mm. from base, subulate towards tips, which are twisted or curled. *Gleba* covering disc and upper surface of base of rays, fetid, gelatinous, olivaceous, almost black when dry. *Spores* olivaceous, elliptical, rounded at both ends, $6 \times 4\ \mu$.

Habitat.—Growing solitary or more rarely crowded amongst decaying leaves on forest-floor.

Distribution.—Australia ; Tasmania ; widely distributed throughout the lowland forests of New Zealand.

This is an extremely variable species, differing considerably in size, number of rays, and colour. In the past this has led to its having been named several times. In the herbarium I have a large number of specimens, and find that such features as the number of rays, size, and colour are by no means constant. For example, forms with six, seven, or eight rays are quite common, and specimens varying in height from 3 cm. to 6 cm. or more

FIG. 1.—*Aseroe rubra* Lab.: mature plant ; eight-rayed form.

may frequently be obtained. Furthermore, colour is by no means a constant character, as specimens may be found in which the colour shades from a bright red to a pallid pink. At Weraroa in May, 1919, I obtained a perfectly white form, the only colour present being that of the gleba.

A. corrugata is not uncommon in New Zealand, and differs but slightly from the typical form. *A. viridis* was separated from *A. rubra* on account of its colour, which was stated to be a metallic green. Later, Berkeley in 1855 included it under *A. Hookeri* (which he separated on account of its small size), because he subsequently obtained specimens resembling this species in form and colour.

Colenso (1883) states that this species was by the Woodville settlers considered fatal to their cats. "They say that their cats eat it, being fond of it, and die soon after." [!]

Buller (1892) quite erroneously claimed that this is an insectivorous plant. In his own words: "I have met with these plants in various parts of New Zealand, always in the depth of the woods, its star-like form and bright colour attracting immediate notice. But what I desire to call attention to now is the singular fact (hitherto unrecorded) that this fungus appears to be insectivorous in its habit of life. . . . Had the surface cup [receptacle], if I may so term it, completely filled with the partially dissolved bodies of dead insects. . . . From the interior of the stem a viscid foul-smelling fluid is secreted, and this rises into the cup and mixes with the bodies of moths, flies, beetles, and other small insects collected there, which appear to undergo a process of gradual dissolution

FIG. 2.—Mature plant; small seven-rayed form. Photographed immediately after it had attained full size.

FIG. 3.—Egg, photographed immediately after it had become ruptured at the apex. Note the arms of the receptacle beginning to show through the volva.

FIG. 4.—Section of an egg shortly before rupture of the volva. Note the cellular mass of the gleba enclosed within the arms of the receptacle, which in turn are enclosed within the gelatinous volva.

All photographs by the writer. All natural size.

and absorption. Now, the question arises, Is this fungus, like *Drosera*, a carnivorous plant, and is it endowed with its pungent odour, added to its flower-like brilliancy, for the purpose of attracting its insect food? And is the fluid a solvent with the acid constituent for aiding the process of digestion? My answer is in the affirmative.

"I dissected one of the stems, and found it was hollow, or nearly so, with what appeared to be a membranous sac at the bottom containing

fluid matter; but the examination, made on the spot, was necessarily a very hasty and imperfect one."

I quite agree with the concluding sentence. As for the rest, it will be seen below that the plant is not insectivorous, and what Buller considered to be the "partially dissolved bodies of dead insects" is in reality the dark-coloured mass of the gleba. He was correct in assuming that the pungent odour and flower-like brilliancy attracted insects, but not for the purpose he imagined.

The mucilaginous gleba covers the upper surface of the disc and portions of the rays. It is dark in colour, and possesses a most fetid odour, resembling somewhat that of decaying fish. In the gleba are embedded the minute spores. The colour of the plant and its conspicuous nature, together with its strong and penetrating odour, serve as a means of attracting insects, particularly blow-flies, which feed on the gleba; the spores, together with the mucilage, are assimilated by the insect, and the former, passing unharmed through the alimentary tract, may, if conditions are favourable, germinate where they happen to be voided.

The development of this species is similar to that of *Clathrus*,* differing in one or two details, especially in the development of the stipe.

Until recently this plant was supposed to be a saprophyte, but Mr. W. M. Carne† has recorded its parasitizing living roots of the grass *Cynodon dactylon* Pers. Another peculiarity he records is that in two specimens seen by him two or three stems emerged from a single volva.

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RELATION OF BIOLOGIC SPECIALIZATION IN THE TAXONOMY OF THE GRASS-RUSTS.‡

By G. H. CUNNINGHAM, Mycologist, Biological Laboratory, Department of Agriculture, Wellington, N.Z.

DURING the preparation of a recent monograph (1923) on the Uredinales of New Zealand, both of indigenous and introduced species, the writer met with considerable difficulty in determining the hosts, distribution, and specific names of many of the cereal and grass rusts. Indeed, so confusing is the literature dealing with the rusts that parasitize members of the Gramineae that the following notes have been prepared to show the complexity of the views expressed in the literature dealing with the cereal rusts, and as an attempt at their simplification. A summation

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* CUNNINGHAM, G. H., *Clathrus cibarius*, or "Bird-cage Fungus," *N.Z. Jour. Sci. & Tech.*, vol. 5, p. 247, 1922.

† CARNE, W. M., in Lloyd's *Mycological Notes*, vol. 7, p. 1117, 1922, Cincinnati.

‡ Read before the Australasian Association for the Advancement of Science, 16th January, 1923.

merely is given, for complete references to all the literature would extend this paper to many times its present length.

Before proceeding further it may be as well to mention that it is necessary for the taxonomist clearly to define what to his mind constitutes a species, so that some semblance of order may be preserved in any systematic paper he undertakes. From a survey of the many conflicting statements of reputable experimentalists set out below it becomes obvious that some line of defence (as it were) must be maintained by the taxonomist against the (to him) unnecessary and endless multiplication of specific names. With this end in view the writer has brought together certain evidence to justify the complaint of unnecessary name-multiplication. For, unless and until some such stand is taken, it is possible that any well-known specific name may at any moment be changed. That they are frequently being changed is obvious when the continually swelling synonymic list under each species is considered.

In this paper four only of the better-known heteroecious species are dealt with—namely, *Puccinia graminis* Pers., *P. coronata* Cda., *P. dispersa* Erikss. et Henn., and *P. Elymi* Westnd. As these species all infect cereals, and are therefore of the greatest economic importance, the literature dealing with them is extensive and complex.

HISTORICAL INTRODUCTION.

Towards the latter part of the sixteenth century it was well known to many agriculturists that the rusts on barberry (*Berberis vulgaris* L.) and wheat were in some manner connected, but no definite evidence on this point was obtained until Schoeler (1818) demonstrated the connection by actual experiment. Little credence was given to his paper by scientists of that period, however, so that the matter remained at issue until the appearance of De Bary's classical paper (1865) in which he verified the connection. De Bary first sowed teleutospores from wheat on the leaves of barberry and obtained aecidia, and in the following year carried out the converse experiment, sowing aecidiospores from barberry on the blades of wheat-seedlings and obtaining uredospores. His success led De Bary to experiment with the spores of *Puccinia coronata*, and he proved that this species also was heteroecious, the aecidium occurring on *Rhamnus Frangula*.

The publication of this paper led to work on various rusts by other experimentalists, with the result that in a few years many heteroecious species were proved to exist.

In consequence of this cultural work, workers found that certain species exhibited what is now known as biologic specialization. Little notice was taken of this phenomenon until the appearance of Eriksson's paper "On the Specialization of Parasitism of the Cereal Rusts" (1894). Although he was not the first to draw attention to this specialization, he was the first to point out that it suggested a possible method whereby "species" could be separated. This paper gave great impetus to researches in connection with specialization of parasitism in the rusts, work which has continued to the present day.

Puccinia graminis Pers.

In his paper (1894) Eriksson, as a result of numerous cultures, stated that he found teleutospores from many hosts would infect barberry, but that the aecidiospores so produced were, in their capacity for infection, limited to certain associated groups of hosts. Further experiments soon demonstrated the fact that the aecidiospores produced on barberry as a

result of infection with teleutospores taken from (say) wheat would only infect wheat; teleutospores from *Agrostis* would only infect *Agrostis;* and so on: in other words, that certain races showed definite specialization. To these races he applied the term *specialisierte Formen*, and in his paper listed several, together with the hosts to which they were confined.

In a later paper (1901) he summarized this experimental work, as under :—

1. *Puccinia graminis* Pers. Aecidium on *Berberis vulgaris.*
    1. f. *Secalis.* On rye.
    2. f. *Avenae.* On oat.
    3. f. *Tritici.* On wheat.
    4. f. *Airae.* On *Aira caespitosa.*
    5. f. *Agrostidis.* On *Agrostis* spp.
    6. f. *Poae.* On *Poa* spp.
2. *Puccinia Phlei-pratensis* Erikss. et Henn. Aecidium unknown. On timothy. (This latter species was separated by Eriksson and Henning (1894, p. 140) on account of inability of the teleutospores to infect barberry.)

Eriksson insisted on the rigid specialization of these races, but results obtained by subsequent workers do not bear this out. For example, Carleton (1899), working with practically the same races, obtained quite different results. He claimed that in North America there were only two special forms (races) as under :—

1. f. *Tritici.* On wheat, barley, cocksfoot, *Agrostis alba, Festuca gigantea, Koeleria cristata,* and *Hordeum murinum.*
2. f. *Avenae.* On oat, cocksfoot, *Avena fatua, A. pratensis, Hordeum murinum, Koeleria cristata, Holcus mollis,* &c.

Jaczewski (1910), working in Russia with similar material, obtained results that showed he was working with five biological races, equivalent to—1, f. *Secalis;* 2, f. *Tritici;* 3, f. *Avenae;* 4, f. *Hordei;* 5, f. *Agrostidis.*

Stakman and Piemeisel (1917), working with this species from both cereals and grasses, separated, as a result of numerous cultures, the following six biological races: 1, f. *Tritici;* 2, f. *Tritici-compacti;* 3, f. *Secalis;* 4, f. *Avenae;* 5, f. *Phlei-pratensis;* 6, f. *Agrostidis.* They claim (*l.c.*, p. 484) that, although the uredospores of these races are similar in size and shape, yet if large numbers are measured, and the biometrical mode determined, appreciable and fairly constant differences become apparent, *provided the spores measured be taken from congenial hosts.* [The italics are ours.] They state, moreover, that "more than one biologic form (race) may occur on the same host in nature, sometimes even on the same plant."

In a recent paper (1922) Stakman and Levine record the discovery of some thirty-seven biological races on wheat. *Puccinia Phlei-pratensis* Erikss. et Henn. is by Stakman and Piemeisel included as a biological race of *P. graminis*, and not considered as a distinct species. This has been done as the result of cultural work recorded in two previous papers (Stakman and Jensen, 1915; Stakman and Piemeisel, 1916). In the former paper the authors claimed that by direct transference of uredospores from timothy they were able to infect several cereals and grasses, thus showing that this race is not limited to the one host, as Eriksson claimed.

As much of the experimental work discussed above has been carried out with uredospores, it might be supposed that different results would be obtained if the cultures were performed with aecidiospores and teleutospores, especially as the aecidium has, by several authors, been considered either the result of a sexual process (Massee, 1888 ; Blackman, 1904) or a device to reinvigorate the organism (Arthur, 1903 ; Bolley and Prichard, 1906).

Eriksson (1896), after numerous experiments, claimed that the aecidium did not influence the biologic races dealt with to the extent of causing them to become more vigorous or widespread in infective capabilities. This statement is supported by Stakman, Piemeisel, and Levine (1918), who, after cultural work extending over four seasons, came to the conclusion that " barberry does not increase the host range of biologic forms, nor does it act as a reinvigorator of the rust. The biologic specialization in the aecial stage is apparently the same as that in the uredinial stage." Arthur (1920, p. 228), on the other hand, claims that the aecidium exerts a reinvigorating influence, for he states, " More extended work is planned in regard to the problem of the transfer of this pernicious black or stem rust from wild grasses to the cultivated cereals, but enough has been accomplished to warrant the statement that although in the uredinial stage this rust shows racial strains that inhibit the ready transfer from one species to another, yet in the aecial stage racial strains play no part, and the barberry acts as a bridging host between each and every other gramineous host."

Puccinia coronata Cda.

Corda (1837) applied to a species of *Puccinia* characterized by the coronate apex of the teleutospore the specific name *coronata*. Nielsen (1875) showed that when aecidiospores from *Rhamnus cathartica* were sown on leaves of *Lolium perenne* uredospores appeared, whereas when aecidiospores from *Rhamnus Frangula* were used no infection resulted. Consequently he considered the former race to be sufficiently distinct to be considered as a separate species, which he named *Puccinia Lolii*. Seventeen years later Klebahn (1894, p. 135) sowed teleutospores from *Lolium perenne* on *Rhamnus Frangula* and *R. cathartica* respectively, and, as he obtained infection on the latter host, he proposed separating this race as a distinct species, for which he suggested the name *P. coronifera*, apparently overlooking the fact that it had previously been isolated and named by Nielsen. He also verified the connection between the aecidium on *Rhamnus Frangula* and *Puccinia coronata*. In passing, it may be mentioned that the aecidia of these two races are morphologically identical.

Eriksson (1894) divided each of these so-called species into five races. In a later paper (1908) he revised his previous work and split *P. Lolii* into eight races, allowing *P. coronata* to remain as in his previous paper. Carelton (1899), on the other hand, claimed that there is but one host of *P. Lolii* in nature. As these races have not been considered as being specifically distinct, it is not necessary to detail them here.

Puccinia dispersa Erikss. et Henn.

This species was at first included in the aggregate *P. rubigo-vera* Wint., but was separated by Eriksson and Henning (1894), together with *P. glumarum* Erikss. et Henn. and *P. simplex* Erikss. et Henn., on account of certain morphological differences, principally in the uredosori. The same year (1894) Eriksson claimed that *P. glumarum* and *P. dispersa* each consisted of five

biological races. In a later work (1899) he revised his previous work and divided the original *P. rubigo-vera* into the following species :—

1. *Puccinia glumarum* Erikss. et Henn. Aecidium unknown.
2. *Puccinia dispersa* Erikss. Aecidium on *Anchusa* sp.
   Grove (1913, p. 261) stated that if this specific name were retained confusion would follow, as it had previously been used by Eriksson and Henning ; he therefore proposed to name this race *P. secalina* Grove.
3. *Puccinia triticina* Erikss. Aecidium unknown. (Since shown to occur on *Thalictrum* spp.)
4. *Puccinia bromina* Erikss. Aecidium unknown.
   F. Mueller (1901) found by the aid of cultures that the aecidium of this race occurred on *Symphytum officinale* L., and accordingly named it *P. Symphyi-bromorum* F. Meull.
5. *Puccinia agropyrina* Erikss. Aecidium unknown.
6. *Puccinia holcina* Erikss. Aecidium unknown.
7. *Puccinia Triseti* Erikss. Aecidium unknown.
8. *Puccinia simplex* Erikss. et Henn. Aecidium unknown. (Now known to occur on *Ornithogalum* sp.)

Of these, Arthur and Fromme (1920) recognize Nos. 1, 2, 6, and 8 (as *Dicaeoma glumarum* Arth. and Fromme, *D. Asperifolii* Kuntze, *D. holcinum* Arth. and Fromme, and *D. anomalum* Arth. and Fromme). *Puccinia triticina* Erikss. and *P. agropyrina* Erikss. they include as synonyms under *Dicaeoma Clematidis* Arth. (= *P. Elymi* Westnd.).

Puccinia Elymi Westnd. (1851).

The uredo- and teleuto-spores of this species occur on several species and genera of the Gramineae, the aecidia on several species and genera of the Ranunculaceae, and because of these numerous hosts many races have been described as distinct species.

For example, Plowright (1885), through cultures, found that an aecidium on *Ranunculus acris* was the first stage in the cycle of a *Puccinia* on *Alopecurus pratensis ;* this race he named as *Puccinia perplexans* Plowr.

Three years later (1889) he sowed teleutospores from *Agropyron repens* on *Thalictrum flavum* and obtained aecidia ; he carried out the converse experiment and obtained uredospores ; consequently he decided that he was working with an undescribed species, to which he gave the name *Puccinia persistens* Plowr.

Later (1890) he worked out by the aid of cultures the connection between an aecidium on *Aquilegia vulgaris* and a *Puccinia* on *Agrostis alba* and *A. vulgaris ;* as a result he erected the species *Puccinia Agrostidis* Plowr.

Ellis and Everhart (1892) described as new a species of *Puccinia* on *Agropyron* spp.—*Puccinia Agropyri* Ell. et Ev. Dietel (1892) infected leaves of *Clematis vitalba* with teleutospores of this species from *Agropyron glaucum*, and, as a result, concluded that this aecidium was a stage in the cycle of *P. Agropyri* Ell. et Ev.

Juel (1894) connected by cultures an aecidium on *Thalictrum alpinum* with a *Puccinia* on *Agrostis* sp. and *Anthoxanthum* sp. : to this he gave the name *P. borealis* Juel.

Rostrup (1898), with aecidiospores from *Thalictrum minus*, succeeded in infecting *Elymus arenarius*, and, as a result, considered this aecidium to be a stage in the cycle of *P. Elymi* Westnd.

Eriksson (1899), on account of their biologic specialization, separated as distinct species *P. triticina* Erikss. and *P. agropyrina* Erikss. from the collective species *P. rubigo-vera* Wint. These were subsequently placed by Arthur and Fromme (1920) under *Dicaeoma Clematidis* Arth., a procedure in part confirmed by the later work of Jackson and Mains (1921).

Ed. Fischer (1901) connected an aecidium on *Actaea* with teleutospores of a species of *Puccinia* on *Agropyron* sp.: to this he gave the name *P. Actaeae-Agropyri* Ed. Fisch.

Arthur (1909), by the aid of cultures, connected an aecidium on *Thalictrum dioicum* with teleutospores of a *Puccinia* on *Bromus Porteri:* this he named *P. alternans* Arth. The following year (1910) he recorded successful inoculations of *Aquilegia canadensis* with teleutospores of a *Puccinia* from *Agropyron biflorum:* this he named *P. obliterata* Arth.

E. Mayor (1911) connected an aecidium on *Actaea spicata* with uredo- and teleuto-spores on *Elymus europaeus:* to this race he gave the name *P. Actaeae-Elymi* E. Mayor.

Jackson and Mains (1921) discovered that the hitherto unknown aecidium of "*Puccinia triticina* Erikss." occurred on several species of *Thalictrum.* They consider that, on account of the morphology and host relationships, this species is "closely related to *Puccinia persistens*, *P. borealis*, *P. alternans*, *P. obliterata*, *P. Elymi*, and *P. Agropyri*, but is separable from these rusts by its sharp biologic limitation to wheat." This largely confirms the work of Arthur and Fromme (1920, p. 333), who include all these races, on account of their morphological similarity, under *Dicaeoma Clematidis* Arth. As their name cannot hold under the International Rules of Botanical Nomenclature, so the species must be called *Puccinia Elymi* Westnd., as this was the first name applied to the perfect stage when placed in the correct genus.

CONCLUSION.

From a consideration of the statements set out above it becomes obvious that the earlier workers considered all races showing biologic specialization of sufficient importance to raise to specific rank, regardless of the absence of morphological differences. It becomes equally clear that the modern tendency is to limit species to those possessing morphological differences, and to group under one species all races resembling one another, regardless of the fact that they may differ greatly in their biologic specialization. In other words, to-day biologic specialization alone is not considered a specific character. As to whether the presence or absence of an aecidium should be considered a character sufficient to warrant the separation of a species is a matter that would to a great extent depend on the evidence brought forward in support. For instance, if it is claimed that the aecidium is absent from the cycle of a certain species, and this claim is made merely on negative cultures (negative evidence), the writer believes that this cannot be accepted as evidence upon which to separate a species. On the other hand, if failure to produce aecidia by the aid of cultures is supported by evidence as to the presence of spermogones associated with the uredosori or teleutosori, then results may be capable of a different interpretation. Similarly, if the aecidia upon different hosts resemble one another morphologically, and if they have been connected by cultures with teleutospores also resembling one another, the fact that they each exhibit definite

and clear-cut specialization does not indicate that they are separate species; they should be classed as races of the same species.

For example, Eriksson and Henning separated *P. Phlei-pratensis* from *P. graminis*, the reason given being that teleutospores from hosts of *P. graminis* would infect barberry, whilst those from timothy (the host of their *P. Phlei-pratensis*) were incapable of doing so. Stakman and Piemeisel, whilst admitting they could not infect barberry with teleutospores from timothy, showed by numerous cultures that the uredospores of this race were quite capable of producing uredospores on numerous cereals and grasses, hosts of several races of *P. graminis*, and that the resultant spores were identical with uredospores of other races of *P. graminis*. Therefore they concluded that *P. Phlei-pratensis* was but a biological race of *P. graminis*. If the absence of an aecidium in this case is considered sufficient to separate a species, then the form of *P. graminis* occurring in New Zealand, Australia, and South Africa must be considered as specifically distinct from the European form, for although it is common on many introduced and indigenous cereals and grasses, yet in no single instance in any of these countries has the aecidium been obtained on barberry, either in nature or from cultures.*

The synonymy of this species then is :—

Puccinia graminis Pers.

1. *Puccinia Phlei-pratensis* Erikss. et Henn.

Puccinia coronata Cda.—This is usually split into two species on account of the biologic specialization exhibited by the aecidia. As the writer believes that only one morphological species exists in nature, he would arrange the synonymy as under :—

Puccinia coronata Cda.

1. *Puccinia Lolii* Niels.
   Puccinia coronifera Kleb.

Puccinia dispersa Erikss. et Henn., it will be remembered, was derived from the collective *P. rubigo-vera* Wint. Then Eriksson split *P. rubigo-vera* into eight species, most of which are based on biologic grounds only, and consequently cannot be recognized. Therefore the synonymy is as follows :—

Puccinia dispersa Erikss. et Henn.

1. *Puccinia dispersa* Erikss.
   P. secalina Grove.
2. *Puccinia triticina* Erikss.
3. *Puccinia bromina* Erikss.
   P. Symphyti-bromorum F. Muell.
4. *Puccinia agropyrina* Erikss.
5. *Puccinia Triseti* Erikss.

In reality Nos. 2 and 4 are synonyms of the following species, but are retained here to show their derivation.

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* Since the above was written the writer has seen a paper by Waterhouse (*Proc. Roy. Soc. N.S.W.*, vol. 55, pp. 278–88, 1922) in which he records successful innoculation of barberry with teleutospores collected from wheat-plants grown in Australia. Although the results were obtained under highly artificial conditions, his experiments show that one at least of the Australian biological races are still capable of producing aecidia.

Puccinia Elymi Westnd. has been split into many so-called species on account of the fact that the aecidia of different races occur on many different hosts. Later work has shown that these races do not exhibit even biologic distinctions; consequently the synonymy is as under:—

Puccinia Elymi Westnd.

1. *P. perplexans* Plowr.
2. *P. persistens* Plowr.
3. *P. Agrostidis* Plowr.
4. *P. Agropyri* Ell. et Ev.
5. *P. borealis* Juel.
6. *P. Actaeae-Agropyri* Ed. Fisch.
7. *P. Actaeae-Elymi* E. Mayor.
8. *P. alternans* Arth.
9. *P. obliterata* Arth.
   (*P. agropyrina* Erikss.).
   (*P. triticina* Erikss.).

Many other examples could be cited, but the examples chosen will illustrate the complexity of modern taxonomy. Although only four species are discussed in this paper, yet nineteen synonyms are listed, all the outcome of so-called species based on biologic distinctions alone. This by no means includes all, as there are forty-five for *P. Elmyi* alone; but as thirty-four of these are not due to cultural work they have been omitted here.

When it is considered that few workers have obtained similar results when working with similar material, and that a great deal of the evidence submitted in support of the erection of species is negative evidence, it becomes obvious that the taxonomist can place little reliance upon cultural work as a basis for specific determination, and this fact would appear to strengthen the contention of Marshall Ward (1905) that "no species can be accepted as valid until it is capable of definition in morphological terms."

In conclusion the writer would like to state that he does not wish to disparage cultural work—far from it; as an economic mycologist he fully realizes the debt mycologists and plant pathologists owe to those workers who have engaged in this exacting research, particularly to those who have devoted so much time to the problem of cereal rusts, their biology, distribution, and possible control. At the same time he believes that, from the taxonomist's point of view, this work must of necessity be given little credence, partly because the taxonomist so frequently has to work with herbarium material, but principally because there is the danger that unless some such stand is taken we may in the future be confronted by some publication based on the lines laid down by Probst (1909), who claimed that a certain species of *Puccinia* was confined to a single form of a variety of a species of the host genus *Hieracium*. Carry this to its ultimate conclusion and systematic work would become unnecessary, as each rust on each individual plant could be considered as a distinct species, and named accordingly.

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THE NEW ZEALAND SMELT, *RETROPINNA RETROPINNA.*

By W. J. PHILLIPPS, F.L.S., F.R.G.S.

Order ISOSPONDYLI (Herrings and Trout-like Fishes).

Family RETROPINNIDAE.

THE fishes of the family Retropinnidae are peculiar to the fresh and brackish waters of New Zealand, the temperate zones of the eastern and southern coasts of Australia, and Tasmania. They are closely related to the Salmonidae (salmon and trout) of the Northern Hemisphere, agreeing in the possession of a posterior adipose fin, but disagreeing in the fact that in the smelts the dorsal is situated far back above the vent, and partly opposite the anal fin. There are six ventral rays. Teeth are present on both jaws, on the vomer, palatines, and tongue.

One genus, *Retropinna*, is recognized, of which McCulloch, 1920 (*Rec. Aust. Mus.*, vol. 13, no. 2, pp. 47–54), has distinguished three species. These are: *Retropinna retropinna*, from New Zealand; *Retropinna semoni*, generally distributed in the Australian region; and *Retropinna tasmanica*, from Tasmania. A cotype of *Retropinna retropinna* was received by Mr. McCulloch from the British Museum, and described for comparison with the Australian examples. It appears, however, that in describing *Argentina retropinna* Richardson, 1845 (*Ichth. Ereb. and Terr.*, pt. 5, p. 121), had specimens only from 2 in. to $3\frac{1}{2}$ in. long. These were apparently in a larval or post-larval stage.

In October, 1921, Mr. W. B. Braddon, of Hokitika, secured an adult smelt in the estuary of the Hokitika River, and presented it to the Dominion Museum. This specimen is here figured, and is 5·3 in., or 136 mm., in total length. As certain marked characters are evident which do not appear in younger examples the following notes may be of interest.

The fin rays are as follows: Dorsal, 3/9; anal, 3/17; pectoral, 11; ventral, 6; caudal, 18. The scales in the lateral line are not easily discernible. Various counts gave from 60 to 63. The length of head is 2·17 times the length of the first branched dorsal ray, twice the first branched anal ray, 1·7 times length of pectoral, and 2·4 times the ventral. The anal fin commences below the base of the dorsal slightly posterior to the middle point. The depth of the body before the ventral fins may be taken 5·4 times in the length of body to the hypural joint, while the head may be taken 4·4 in same.

The head is just over $\frac{1}{5}$ the total length of the fish. The lower jaw is longest. The maxillary bone reaches back to a point under the eye slightly posterior to a vertical line drawn through the centre of the pupil. It is noticeable that the maxillary appears to be much less developed in the young. The interocular space is slightly greater than the length of the snout, which is a little longer than the diameter of the eye. Length of head is 3·8 times that of snout. Mandibular teeth are partly biserial. There are large irregularly placed hooked teeth on each side of the tongue. Vomerine and palatine teeth are in a single series.

In describing the adult under the name of *Retropinna osmeroides* Hector, 1871 (*Trans. N.Z. Inst.*, vol. 3, p. 134), states: "These fish were seen in October in immense shoals leaping out of the water in a very lively fashion, and following the tide into all the narrow tributary streams to which the brackish water penetrated. All individuals were alike in size, the length being about 7 in."

Hutton, 1872 (*Fishes of N.Z.*, p. 58), states that in the Waikato they go down to the sea to spawn in April, and the young fish return in October.

[*H. Hamilton, photo.*

NEW ZEALAND SMELT.

Mr. W. B. Braddon has for many years kept a methodical record of migrations of fish in the Hokitika River, and has kindly given me permission to use his notes. The following are of interest here:—

Year 1910: October 24, smelt fry commenced to run up river. November 18, adult smelts running up-stream in shoals.

Year 1913: October 6, large smelt taken apparently running down-stream; ova about the size of sugar-grains came away freely. October 14, number of large smelts taken, nearly all contained ova ready for extrusion. October 24, smelt fry up to over 2 in. in length commenced running up-stream. November 9, adults running up-stream (after spawning ?).

Year 1914: October 26, 27, shoals of adults running up-stream. November 5, adult smelts running up-stream.

Reviewing the above data, it will be seen that the only questionable statement is that made by Hutton to the effect that the adult smelt runs down-stream in April. Probably the adult minnow is here referred to. Hector found the young and adults, which he considered two distinct species, together in fresh water in November. These may have just arrived up-stream. The specimens mentioned by Hector, secured in gravid condition in November, may have been migrating to the estuary, or may have already visited the estuary. Though the latter is unlikely, further proof is required as to the condition of adult smelts running up-stream in October and November.

It is possible that the smelt deposits its ova in the brackish water in October and November, the eggs or young being carried out to sea. The young smelt, 2 in. to 3 in. long, is taken annually during October and November as it ascends the estuary of the Hokitika River direct from the sea. From the above it will be seen that the young fish, sometimes sold as "whitebait," is most probably a year-old larval form.

AN ATTEMPTED ACCLIMATIZATION OF RAINBOW TROUT IN SAMOA.

By W. J. PHILLIPPS, F.L.S., F.R.G.S.

EARLY in the year 1910 Mr. G. Kronfeld, then German Consul at Auckland, made representations to the New Zealand Government Tourist Department, on behalf of Dr. Solf, Governor of Samoa, requesting that the Samoan Administration be supplied with a consignment of eggs of rainbow trout, *Salmo irideus*. About the 20th July, 1910, 5,000 trout-eggs, or "eyed ova," as they are usually termed, were forwarded together with the necessary instructions to the Samoan authorities, from the Government trout-hatchery, Rotorua, then in charge of the Tourist Department. Owing to some unfortunate incident the instructions did not reach Samoa until after the eggs had arrived.

Some three months after the above date inquiry was made by the Tourist Department in regard to the relative success of the experiment. In due course a reply in German was received, which, through the courtesy of Mr. W. Cobeldick, F.R.G.S., I have been enabled to examine, together with other particulars supplied to me. A summary of a translation of the letter is as follows :—

"Out of the 5,000 ova, only the two upper layers of the case arrived in good order, eggs in the remaining layers being either dead or mouldy. The ice had cooled the upper layers of the case during the journey, but no attention had been given to the lower layers.

"Hatching-trays were set up in Samoa beside a stream having an average temperature of 24° C. or 75° F., and eggs gradually brought to this temperature and hatched. The supply of water was brought in two $\frac{3}{4}$ in. pipes after having passed through a sieve. The pipes had an outlet about 6 in. above the water in the troughs in which the eggs were hatching.

"Dead ova and fry were removed daily. All living eggs hatched four days after arrival. On the fifth day hatching-trays were completely cleaned out. A considerable amount of dirt and fungus was removed. Many of the recently hatched fish were already dead. After sixteen days only thirty-three fish remained alive. Several showed a swelling of the abdomen, and a number more died.

"On the sixteenth day feeding commenced. The fish ate greedily, and for three days there were no deaths among the twenty-two survivors; but on the twenty-second day they commenced to die again without apparent cause. The trough was cleaned daily. Instructions arrived on the twenty-fifth day.

"Four weeks after arrival eight healthy fry were liberated in the river underneath a waterfall. As all waters here contain eels, crabs, robber-fish, &c., there is little hope that they will survive.

"Dr. E. S. ——,
"For Governor-General."

The eggs suffered from lack of attention on board ship, and the chances of success would naturally have been much greater had the number of eggs been 100,000. On a journey of this kind it is most important that dead eggs should be instantly removed, and the temperature of the trays retained at about 42° F. The water supplying the hatching-boxes in Samoa appears to have been insufficient both in quantity supplied to the eggs and fry, and in respect to the amount of dissolved oxygen due to inadequate aeration.

THE RECLAMATION OF SANDY LOWLANDS.*

By P. E. BALDWIN, Barrister-at-law.

THIS paper deals with the bringing into profitable use of the sandy country on this coast: I am referring to the very large area of land stretching along the sea-coast from Taranaki to Paekakariki. This land, as is not common in New Zealand with large areas, presents certain well-marked and peculiar characteristics with regard to climate, soil, and drainage. Taken throughout, the entire tract is of the same general character. It consists of two classes of country similar in their nature. In large part it comprises hills and flats, covered in their native state with manuka scrub and fern. When the scrub is removed these areas clothe themselves naturally with the poorer and more useless grasses—sweet vernal, fern, and danthonia predominating; utuwai also flourishes, and in many places sorrel. The balance of the land comprises swamps carrying a dense growth of flax, koromiko, toi, and "nigger-heads."

The climate, taken as a whole, is temperate, and with a copious rainfall, but the autumn is usually dry. The sun temperature on the soil is far higher than in the adjoining bush and alluvial lands, owing to the heating of the sand; while on the flats and swamps, owing to the water-table being close to the surface, and to the extreme radiation, the nights are frequently very cold, with frosts. The area is subject to violent winds of long continuance, the prevailing wind being from the north-west. Practically all the hills in this district have been shaped to a great extent by the wind, and run, in almost every case, from north-west to south-east. The soil is sandy. Recent analysis shows that it contains all soil-constituents, although lacking any appreciable quantity of nitrogen; moreover, it is sour, and in its natural condition there is a dearth, amounting almost to an absence, of humus. The soil, too, has the great disadvantage of blowing badly, the main agent in the formation and increase of sand-drifts being the wind. It is subject to long-continued and violent gales, and in addition the cut of the sand as it travels prevents any useful herbage from growing. These sand-drifts, as a rule, are started (1) by stock (over and over again one sees large drifts formed along cattle-tracks and sheep-tracks, particularly where they are on the side of a hill or through a narrow gully); (2) by rabbits; (3) by some obstruction in a position, where it is subjected to the force of the winds. It is very noticeable, the effect of a stray toi-bush, or lupin-plant, or horehound. In country such as this, where the wind has great play and the soil is extremely light, any obstruction acts as an obstruction acts in a river: it produces extensive scouring.

Turning now to the question of drainage, one outstanding characteristic is the closeness of the water-table to the surface. In very many parts, in winter, it is within less than 1 ft.; and what is further noticeable, and a very extraordinary phenomenon, is that even on the higher levels of the flats, and where there is a distinct fall, the water-table is frequently almost as close to the surface as on the lower levels. At Himatangi,

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* Paper read before the Manawatu Philosophical Society, 13th April, 1923.

which is 60 ft. above sea-level, permanent water is found in summer at about the same level as at Motuiti, which is not more than 30 ft. above sea-level. Water can be got on all the flats all the year round at a very moderate depth, and even in midsummer permanent water can be depended on 8 ft. below the surface.

These, then, are the factors with which we have to deal; and, taking the means by which we can best succeed, I put them in the following order of importance: (1) Drainage; (2) shelter; (3) prevention of new sand-drifts; (4) clothing the formed sand-drifts; (5) amelioration of the soil so as to develop its natural fertility and increase its productiveness; (6) destruction of pests, especially rabbits; and (7) proper stocking.

I have put drainage first: it is the most essential improvement. Until the water-table is lowered on the flats and in the swamps to at least 2 ft. in winter-time valuable grasses will not grow.

The general benefit and results of drainage are well known: I am not going to expatiate on them. Shortly stated, they are an increase in root-run, a warmer temperature, and a favourable environment for soil-organisms. The particular country with which I am concerned is so waterlogged in winter that nothing of any value can be grown there until deep drainage has been provided through the main drainage-outlets and numerous subsidiary drains. Much money has been wasted in draining this class of country, because most of the drains go through the centres of the swamps. This may answer in some cases, but not in this country, where almost all the swamps are the result of seepage from the hills. The drains must follow the hills to be most effective.

I emphasize the need for draining also because to any one looking at the country it seems ridiculous to drain such sandy land; but deep and efficient draining is the beginning of wisdom.

Draining is a cheap matter except in the actual swamps. In these a large quantity of buried timber and the softness of the soil necessitate hand-work. And it is a recurring expense, as the drains constantly fill with vegetation and sandy silt. But they must be kept clean, and if possible steadily deepened. All other draining can be done by a swamp-plough and a draining-grader at probably 3s. per chain, and the drains cleaned by the grader at 1s. per chain.

Shelter is the next main essential. Here again the benefits are so well known as to make any general remarks superfluous. But two reasons emphasize its supreme value in this class of country: (1) The prevalence of these high and often very cold winds; (2) the tendency of the country to "blow"—by this I mean to form sand-drifts.

This leads to the consideration of a very important factor: The shelter-belts must be at short intervals, proportioned to the height of the trees. Otherwise there are induced huge sand-drifts such as may be seen on the Foxton line. They lie between Himatangi and Motuiti, on the east side of the railway-line, and have been probably started, and certainly enormously increased, by the wind sweeping down after passing clear over the influence of the great pine plantations on the western side of the line. Where there is any quantity of scrub the difficulty is minimized by leaving belts of scrub. Two chains of scrub can be left across the prevailing wind at intervals of a few chains, and by planting poplar-cuttings through the scrub an absolutely efficient wind-break would soon result. In cases where the scrub has been completely cleared the growing of pine belts presents no serious difficulty. The most satisfactory results

are obtained if the surface of the land has been turned over and exposed to the sweetening of the air. If the land is ploughed and fallowed for about six months *Pinus insignis* makes rapid growth. But here the expense of fencing, and the depredations of rabbits and hares, offer a serious drawback. In the scrub plan these are not practical difficulties.

The prevention of new drifts should present no difficulties to a careful farmer. It is essentially a case of "a stitch in time." Directly sand shows, the owner must get to work. Methods of prevention that suggest themselves are to avoid as far as possible the erection of fences along the sides of the sandhills, and to prevent, if possible, established cattle and also sheep tracks. It pays to put at intervals across any track that is being much used some obstruction such as cut manuka. If in addition the farmer cuts down any isolated bushes of lupin, toi, flax, horehound, growing on high land, and keeps the land clear of rabbit-burrows, he will have no sand-drifts.

The next point is the clothing of the formed drifts. The practice of the modern practical man is an entirely new departure. The old system was to provide some effective obstruction to the wind; marram-grass was the mainstay. Its action is well known. It grows in pure sand; shifting sand does not cut it. After frost stock will eat it; and when thoroughly established it provides shelter for grasses to acclimatize themselves, these being, as a rule, the poorer grasses. The planting is a laborious matter: it must all be done by hand, and unless the shoots are suitable and young, much of it will fail. Moreover, it depends on its strength and not on its lack of resistance. It tends to form banks of sand, and it is a long time before the bulk of the land is pasture—and at its best it is unprofitable pasture. The modern system is to grass the sand-drifts with cocksfoot, clover, and crested dogstail, just as ordinary land is grassed. All these grasses flourish on the bare sand without manure, although by adding manure a quicker growth and heavier sward is the result. I have myself also grown lucerne readily on sand-drifts as high up as 100 ft.

The system would be, of course, too easy and too obvious, after one trial, were it not for the drifting sand, which would not only shift the seed but cut through the young growth. To obviate this difficulty, either before or after the drift is sown down, cut manuka is laid, but not too thickly, over the sand-drift, with the butts facing up-wind, and in actual practice this has proved quite effective.

Mr. W. Renton, manager for many years for Messrs. Barber Bros. at Himatangi, is, I think, the pioneer in this work, and it should revolutionize the grassing of sand-drifts, at any rate on this coast. One difficulty is keeping stock off until the grass is established; but the manuka acts as a great protection, and not only deters animals from grazing there when there is feed elsewhere, but also prevents the grass and herbage from being eaten off low. This system forms a very great advance in the clothing of drifts; and if my experience with lucerne is extended, as I think it can be, there is no doubt that a stand of lucerne can be established as cheaply and as cleanly as in any known way. Many of us no doubt are aware that lucerne has been grown on bare sand, and profitably, in the South Island, but growing it on what were moving sand-drifts has not, as far as I know, been successful before—if, indeed, it has been tried. An added advantage in growing lucerne, clover, and in a lesser degree cocksfoot, is that these (especially lucerne) not only

clothe the drifts, but act, through their vigorous deep-rooted system, as actual sand-binders.

One or two things have got to be borne in mind in dealing with these drifts. The most important is to have no ragged edges: by this I mean, no places where the wind will strike an abrupt gradient. These are usually at or near the top. The method that seems to give the greatest measure of success is to round these places with a scoop, or by hand-labour, and carry the manuka facing well over the top on to the unbroken land beyond.

Having got the land drained, sheltered by shelter-belts, and free from drifts, the only points that require attention are soil-amelioration and destruction of pests, particularly rabbits.

The latter is easy. All the sand country lends itself to cheap poisoning. The rabbits live in the ridges, and if the poison is laid at the foot of the ridges two poisonings will result in a practical clearance. The systems differ. Some men still cling to the old hand system of turning a spit at every few yards and laying the poison on the sod; others use a plough to turn the earth and place the poison at intervals along the slice; while others still find a heavy poisoning on the grass, laid from horseback, is quite effective. The only certainty is that repeated poisonings are necessary, and if done by all the owners simultaneously they are quite effective.

Soil-amelioration depends on two factors—manuring and judicious stocking. Manuring includes, and in this class of country necessarily includes, green-manuring. I have tried three plants—annual lupins, cow-peas, and mustard. Unfortunately, before the results were manifest I sold the land on which I was experimenting. To make the experiment less (or more) satisfactory the rabbits, mostly from a neighbour, took heavy toll of the lupins and cow-peas; but the experiment showed conclusively that very heavy crops of these plants can be grown on desperately sandy land without manure. I have no doubt it would pay handsomely to grow with manure both from the point of view of the green-manure crop and the land itself.

After green-manuring, grass will take readily; but naturally the expense of the operation, which is in its essence unproductive, deters most farmers from carrying it out.

The hills can be readily and cheaply grassed by burning the fern and danthonia, sowing grass-seed—chiefly cocksfoot and crested dogstail—mixed with manure, and then crushing out the fern with cattle. Another method, when hay is grown, is to feed hay at different parts of the paddock on the hills and flats. The seed of the hay where it falls and the seeds carried by the stock will soon make an appreciable and ever greater improvement in the grassing of the land.

On the flats light diskings and seed-sowing is the readiest and cheapest method of improvement; but the necessary accompaniment of all these methods is top-dressing. The whole of these lands respond in a marked degree to top-dressing; and although basic slag, Nauru phosphate, or other phosphate manures have had a wonderful effect, I feel sure that a complete manure would give the best results. I form my opinion mainly because of the effect that flax-vegetation has on the soil, as evidenced by the behaviour of the stock. For years after flax-fibre paddocks have been abandoned and thrown open, both cattle and sheep will show an extraordinary partiality for the grass growing there. It is matter of

common knowledge that, in addition to its nitrogenous content, flax-fibre provides a considerable potash manuring, and in addition the substance of the land benefits in a marked degree by the mechanical improvement from the vegetable refuse.

To sum up, I am sure that if one-half of the manure used in the Waikato per acre were used on these sandy lands the results would far surpass those obtained there. The reason I say so is that much of the better land in this sandy belt, that has probably never had an ounce of manure, carries a large head of stock—nearly up to a beast to an acre and a half—and produces enormous quantities of rich milk, grows fine maize crops, oats, turnips, rape, and hay.

This leads me to the question of judicious and profitable stocking. One outstanding feature is that the land carries cattle better than sheep. The reason is, I think, that sheep eat the grass too close, and thus deprive the land of its natural protection against its two worst enemies—the heat of the sun on the sand, and the extreme radiation from the soil. The one scorches the roots in the hot weather; the other later on perishes them in the cold.

Having shortly dealt with all these matters, the next and a very important question is, Is this land worth all this trouble and expenditure when it has been improved?

I think that any one who has farmed it with any care can only answer in the affirmative. The land has very great advantages. To begin with, it is, even in its unimproved state, extremely warm on the ridges, and usually provided with considerable natural shelter. The stock lie warm. They invariably, according to my experience, camp on the higher ground, except in the very hot weather. Cattle, and also sheep—but particularly cattle—winter well, and dairy cows are free from all the ailments and diseases which form such a serious tax and a serious menace to the dairy-farmer whose cows winter on the rich alluvial flats. The land, I am sure, will grow lucerne as cheaply as any other land. It grows magnificent root crops, and in favourable places I have seen maize, sorghum, and oats as good as that grown on the rich lands of the Kairanga. Moreover, it is healthy, and pigs and poultry do extremely well on it. Practically none of it has been scientifically farmed, but even in the haphazard way most of it has been brought into grass and farmed the results are astonishing. As one slight instance, the tests of the Wellington Corporation showed that the cows supplying the milk from Bainesse, which is entirely land of this character, gave the highest cream test, competing, as that milk was, with milk from the surrounding alluvial land.

There is one other matter about which I wish to say a few words. The policy of New Zealand taxation lends no encouragement to the improvement of land of this character. Owing to the system of taxation a man is taxed and penalized for his industry—a man is directly mulcted in money for expending money on his property; and it should be a serious consideration with the Government of the day whether settlers who have to overcome great natural difficulties (I refer to the man farming these sandy lands, the man farming pumice land, and the man farming the gum lands of the north) should not be taxed on the real unimproved value of the land for a term of years sufficiently long to enable him to reap the reward of his industry. Then, no doubt, after a period of, say, twenty years, it might be fair that his land should be revalued.

DEPARTMENTAL REPORT.

Notes to accompany a Geological Sketch-map of the Mount Arthur District.

By J. HENDERSON.

INTRODUCTION.

THE writer was in the Mount Arthur district from the 6th to the 22nd February, 1923, and hurriedly explored the country in the neighbourhood of the New Zealand Asbestos Supply Company's claim in the upper basin of the Takaka River. Excursions were also made to the Mount Arthur Tableland and to the Leslie and Cobb valleys.

Mr. James Mackay, first Goldfields Warden in New Zealand, traversed part of the district between the sources of the Takaka and Karamea (or Mackay) rivers during 1855, and in 1860, accompanied by Major Lockett, further explored the same area. Gold had been found in the Moutere and along the shores of Massacre Bay in 1853, late in 1856 in the Aorere Valley, and in 1857 in the lower Takaka. In the basin of the latter river, according to Hochstetter,* the coarsest gold occurs in the Waitui, a stream draining the north-east corner of the area here mapped. Hochstetter noted also the association of grains of osmiridium and platiniridium with the detrital gold of the Takaka basin. The diggers probably traced the gold to the head of the Takaka River, which rises on the sloping plateau north of Mount Arthur. That the gravels of the Baton, Wangapeka, Leslie, upper Karamea, and many of their tributaries carried gold was well known in 1860. About this time, however, the discoveries in the upper and middle portions of the Buller Valley were attracting much more attention in Nelson. The bridle-track along the Graham River to the Mount Arthur Tableland and thence down the Leslie Valley seems to have been formed during 1863–64. At that time the principal route to the Buller Valley was by way of Motupiko Valley to Lake Rotoiti; and the Mount Arthur track, besides giving access to districts known to be gold-bearing, was ultimately to be extended along the upper Karamea and the Matiri valleys to the basin of the upper Buller.

The gold-bearing gravels occurring on the high plateau country north of the Mount Arthur Range and in the streams draining therefrom has been worked intermittently for more than half a century. The patches of payable auriferous gravel, though in some cases rich, were generally of small extent, access was difficult, and the climate during winter severe. The field never supported a large population, and is now all but deserted; farmers from the adjacent Motueka Valley may get a few ounces during the summer months.

As early as 1879 gold-bearing quartz leaders were discovered in the headwaters of Gridiron Creek, on the north flank of Gordon's Pyramid, a peak about two miles north of Mount Arthur. These were again prospected between 1909 and 1914, but a workable deposit was not found. Auriferous quartz lodes are known to occur at several other points.

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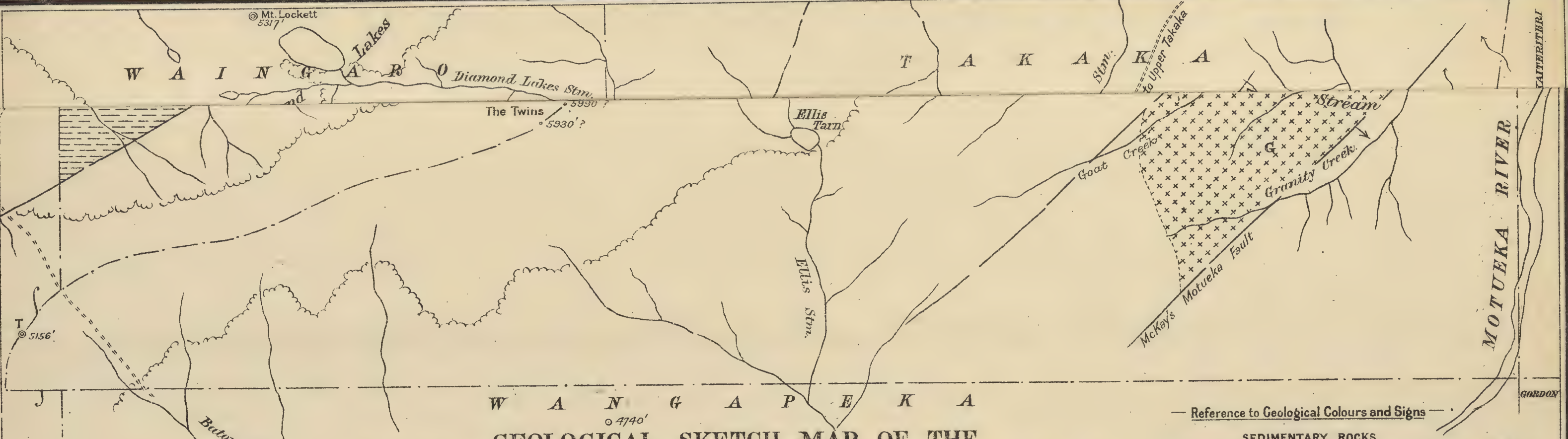
* F. VON HOCHSTETTER, *New Zealand*, p. 107, 1867.



GEOLOGICAL SKETCH MAP OF THE
MOUNT ARTHUR DISTRICT

(Mount Arthur, Matawai, Flora, and Part of Harapaki Survey Districts, Nelson Land District).

Reference

Tracks	*shown thus*
Trigonometrical Stations	" " C 1841'
Edges of Bush	" "
Swamp	" "
Waterfalls and Dams	" "
Crests of Ridges and Saddles	" "

Compiled from data obtained from the Lands and Survey Department, and from additional surveys by J. Henderson of the Geological Survey Branch of the Mines Department. Geology by J. Henderson.

SCALE

CHAINS 80 40 0 1 2 MILES

KILOMETRE 1 ½ 0 1 2 3 KILOMETRES

1 : 63360

Reference to Geological Colours and Signs

SEDIMENTARY ROCKS

TERTIARY — Limestones, sandstones, grits, and fine conglomerates

PALÆOZOIC

IGNEOUS ROCKS

ACIDIC — Granite — G

BASIC & ULTRA-BASIC — B U

Outcrops with observed strike and dip

Outcrops with no visible strike and dip

Outcrops with vertical bedding

Faults — F F

P. G. MORGAN.
DIRECTOR.

Drawn by G.E. Harris, 1923.

GEOLOGICAL SKETCH MAP OF THE
MOUNT ARTHUR DISTRICT

(Mount Arthur, Matawai, Flora, and Part of Harapaki Survey Districts, Nelson Land District).

HARAPAKI
MATAWAI
FLORA
MOUNT ARTHUR
WAINGAPO
TAKAKA
WANGAPEKA
KAITERITERI
GORDON
ANATORI

Mt. Lockett 5317'
Diamond Lakes
Diamond Lakes Stm.
Iron Hill 5530'
Tableland
Cobb
3730'
2600'
Mt. Peel 5352'
4530'
Lake Peel
4700'
Sub B
Balloon Hill 4680'
Deep Stm.
Heath Ck
Arthur
Mount
Malaki Stm.
Balloon Ck.
4220'
Hut
Sub C.
Curtis Ck.
Golden Gully
Sub D
BUTCHER TOWN
Starvation Ridge
H 4150
Peel Stream
Caves
Hut 1300'
1220'
Leslie River
Arthur Creek
The Twins 5990'? 5930'?
T 5156'
Button River
A 3512'
Telco Carbonate band
U River
3380'
3170'
3200'
Asbestos Claim
Chaffey 2700'
T.C. band
Pulluck Ck.
Peat Ck.
2080'
2160'
Ghost Creek
2060'
2180'
Takaka River
Cedar Flat 2180'
2330'
2370'
Gretton Stream
Barron Stm.
to Upper Takaka
F
Waiiti Stream
H Hailes Knob 4205'
Hoary Head 4780'
Crusader 4685'
4270'
McMahon 4400'
3915'
Mt. Hodder
Hodges Ck.
Gridiron Creek
Horseshoe Creek
Flora Stm.
2600'
Slaty Ck.
Loadstone Ck.
2820'
Quartz Creek
2980'
The Loadstone 4752'
Goat Stm.
Gordon's Pyramid GP 4842'
Flora Saddle 3250
Graham Saddle 3100'
FF 2075'
Whitlow 2207'
Graham Stm.
ROAD
Hut Thorne 1500'
Salisbury
Sugar Loaf 3515
Mount Arthur 5868'
Ellis Tarn
Ellis Stm.
Pearse Stream
Goat Creek
Granity Creek
McKay's Motueka Fault
MOTUEKA RIVER

— Reference —

Tracks ---------- shown thus
Trigonometrical Stations ---- " ---- " ---- C ◎ 1841'
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— SCALE —

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KILOMETRE 1 ½ 0 1 2 3 KILOMETRES
1 : 63360

Compiled from data obtained from the Lands and Survey Department, and from additional surveys by J. Henderson of the Geological Survey Branch of the Mines Department.
Geology by J. Henderson.

N.Z. GEOLOGICAL SURVEY
P. G. MORGAN, DIRECTOR.

Drawn by G.E. Harris, 1923.

A lease to prospect for asbestos was obtained in 1889. According to Mr. William Gibbs, Goldfields Warden, this mineral had long been known to occur near the headwaters of the Takaka. From 1897 to 1899 a Christchurch syndicate prospected an asbestos-bearing area and made a bridle-track to the claim. Before this date, settlers who had taken up land in the valley of Cobb River, one of the branches of the Takaka, had formed a pack-track down the Takaka from the old provincial track to "the Tableland" diggings, and it was from this settlers' track that the asbestos claim was reached. The license for mining asbestos lapsed in 1900, but the same area was again prospected between 1907 and 1911 by an Auckland syndicate. The present holders, who later acquired the lease, have sent away a few tons of asbestos.

The district has received little attention from geologists. McKay hurriedly examined it during the early part of 1879. In the summer of 1888 Park explored the basins of the Wangapeka and Owen rivers to the south, and in the winter of 1889 the district immediately to the north of the area here mapped. The following list includes these reports as well as a few others dealing more or less indirectly with the geology and mineral resources of the district :—

A. McKAY, The Baton River and Wangapeka Districts, and Mount Arthur Range, *Rep. Geol. Explor. during 1878–79*, No. 12, pp. 121–31, 1879.

S. H. Cox, On certain Mines in the Nelson and Collingwood Districts, and the Geology of the Riwaka Range, *Rep. Geol. Explor. during 1879–80*, No. 13, pp. 1–3 and 8–9, 1881.

J. PARK, On the Geology of the Owen and Wangapeka Goldfields, *Rep. Geol. Explor. during 1887–88*, pp. 74–88, 1888.

J. PARK, On the Geology of Collingwood County, *Rep. Geol. Explor. during 1888–89*, No. 20, pp. 227–39, 1890.

A. McKAY, On the Crystalline Limestones and so-called Marble Deposits of the Pikikiruna Mountains, Nelson, *Rep. Geol. Explor. during 1890–91*, No. 21, pp. 38–43, 1892.

A. McKAY, Gold Deposits of New Zealand, reprinted from *N.Z. Mines Record*, pp. 11–12, 1903.

ACCESS.

The pack-track formed in the old provincial days is still the principal means of access. This extends from the end of the road at the Graham River forks, a point about two miles and a half from Pokororo Post-office, which is near the junction of the Graham with the Motueka, and about nineteen miles from Motueka Post-office. For the first six miles the track is steeply graded, rising from 470 ft. above sea-level to 3,250 ft. at the Flora saddle. It follows the Flora for six miles to the junction of that stream with the Takaka River (2,330 ft.), whence it has been constructed along the headwater valley of the Takaka to the Tableland, rising about 1,000 ft. in three miles. For two miles the track follows a low ridge on the plateau, and then winds down into the profound valley of the Peel River, descending nearly 3,000 ft. in about six miles. Peel River is a tributary of the Leslie, and the track is continued down the Leslie Valley to the confluence of that stream with the Karamea. From the Flora-Takaka junction a branch track extends to the Cobb Valley and the asbestos claim. Another bridle-track, of much better grade, and in part widened to a road,

extends from Upper Takaka Township through the valleys of Waitui, Baron, and Grecian streams, branches of Takaka River, to the saddle between Ghost Creek (a tributary of the Grecian) and the Takaka River. The track has been formed to this saddle, which is about 2,620 ft. above sea-level, and if extended another mile would reach the Flora track at a point about 2,270 ft. above the sea. There is a foot-track through the bush less than half a mile in length joining the two bridle-tracks. Upper Takaka Post-office (about 380 ft.) is sixteen miles by excellent road from the Port of Takaka.

PHYSIOGRAPHY.

The Mount Arthur Range, which traverses the district in a north-east direction, forms the watershed between the south-east-flowing Graham, Pearce, and Baton streams, tributaries of the Motueka River, and the sources of the Takaka and Leslie rivers, which drain the north-west side of the range. A sloping plateau, now deeply dissected by valleys, rises gently to the westward from the north-west flank of the range. This is variously known as Salisbury Plateau, the Mount Arthur Tableland, or, briefly, "the Tableland." The first-mentioned name is derived from that of two early settlers and explorers, whose sons still live in the Motueka Valley. The south-east edge of the Tableland, abutting against the Mount Arthur Range, increases in height from about 2,000 ft. on the northern boundary of the area mapped to more than 3,000 ft. in the centre of the same area. This is a consequence of the upward slope to the west already mentioned. Mounts Lockett (5,317 ft.), Iron Hill (5,500 ft.), and Peel (5,352 ft.) are on the high western edge of the Tableland. The Takaka River flows north-north-eastward near the base of the Mount Arthur Range, from which its principal tributaries are Flora, Grecian, Baron, and Waitui streams. The drainage of the sloping plateau is by subparallel eastward-flowing streams, of which the largest is the Cobb River. The Leslie River, which flows south-west to the Karamea, is more deeply entrenched in the plateau than the Takaka, but, like it, flows close to the base of the Mount Arthur Range. Its principal tributary in this district is Peel River, which flows south from Mount Peel.

On the Tableland most of the small streams flow in mature swampy valleys little below the general surface, but pass into narrow tortuous valleys through which they descend by a series of falls. The Peel, the Leslie above Peel Junction, the Takaka and its branches, and the Cobb for a few miles above its confluence with the Takaka, flow over rock bottoms in narrow V-shaped valleys with interlocking spurs. Below Peel Junction the Leslie flows westward at grade through wide, wooded gravel-flats for five miles to Karamea River. This latter, a decidedly larger stream, flows from the south-west along a similar valley, but, after receiving the Leslie, turns abruptly west (Karamea Bend), and soon enters the series of granite gorges of its middle course, in which it descends about 1,000 ft. The mature valleys of the Leslie and upper Karamea were probably formed when the land was about 1,000 ft. lower than at present. Supporting evidence is furnished by high-level terraces in the neighbourhood of Upper Takaka, and by the alluvial flat in the upper valley of the west branch of Graham Stream, where a mature valley extends for about a mile up-stream from Thorn's Hut (1,500 ft.). Remnants of the same valley-floor, not yet removed by the deeply entrenched Graham, extend a similar distance down-stream.

No permanent snowfields occur in the district, but on the higher country the evidences of former colder conditions are abundant. Lake Peel, which

is merely a tarn, occupies a typical glacial cirque, and several small tarns, now drained or filled in, occur in the headwater branches of Peel River. The Diamond Lakes, between Iron Hill and Mount Lockett, and the many small tarns six miles north-west of Mount Peel, are also of glacial origin. The rocks near the overflow of Lake Peel have obviously been smoothed by ice, and Deep Creek, which drains from the lake, drops over a precipice immediately below it into a straight U-shaped valley without interlocking spurs. Immediately south-east of the Lake Peel cirque is another smaller cirque which also drains into the end of this glacial trough.

The Cobb River meanders on the floor of a flat-bottomed valley for ten miles before entering a narrow gorge about a mile above the junction of Diamond Lakes Stream. The valley is steep-sided, without interlocking spurs, and with many subsidiary hanging valleys. From its head the course for five miles is south-east, but near Mount Peel it turns east and then north-east, the change in direction being by a gentle smooth curve,

FIG. 1.—Ice-worn conglomerate, Lake Peel.

near which is a low hummocky rock-terrace, probably representing a shallow step across the valley-bottom. Similar low hummocky rock-terraces occur at several points farther down-stream, but these, which do not extend across the valley, are thought to be the truncated remnants of the spurs of the original stream-eroded valley. On the south-east side of the lower valley and between 500 ft. and 600 ft. above its floor a decided shoulder in the slope of the valley-wall is visible. The less-steep upper portion of the slope is strewn with large angular and subangular fragments of rock of several types; in some places these are so numerous as to suggest that the valley flank is formed of moraine. Such a moraine or moraine-covered rock-ridge extends for a mile or more in a westerly direction from the head of Peat Creek. This stream and Bullock Creek, both small eastward-flowing branches of Takaka River, rise in a rock-floored broadly U-shaped depression, half a mile wide, which breaks the continuity of the south valley-wall of Cobb River at a point about four miles east of Mount Peel. Boulders of many rock-types occur on the floor of the depression, which is about 600 ft. above the Cobb and 3,200 ft. above sea-level, along the ridge between Peat and Bullock creeks, and also on

the asbestos claim (up to a height of about 2,800 ft.). Immediately north-east of the gap similar boulders were observed up to a height of 3,600 ft., and they occur for at least two miles farther along the south-eastern side of the Cobb Valley. Evidently the ancient Cobb Glacier in part crept eastward through the gap and in part north-eastward along the present valley, which continues wide and open to a point half a mile south-west of Trig. A. Here the river enters the narrow gorge through which it flows to its junction with the Takaka. This gorge, in its upper part, in the neighbourhood of the loop north-west of Trig. A, appears to be cut in a valley-floor several hundred feet above the stream, which may represent the valley-bottom at the lower end of the old glacier, the up-stream more deeply excavated trough being the overdeepened channel of the ice-stream. According to this view, a lake, since drained by the cutting of the gorge, must have occupied the trough after the ice had retreated. The valley was not explored, and it is not known if delta or lake deposits occur at

FIG. 2.—View looking down Lower Cobb Valley.

its upper end or beach deposits along its sides. The distribution of the vegetation in the valley may have significance in this connection. In its lower half the bottom and sides for 200 ft. to 300 ft. up are in grass, whereas the higher slopes for several hundred feet are clothed with rather stunted forest, which also reaches the floor of the upper part of the valley, but does not completely cover it. Perhaps the lake has been drained so recently that the forest-trees, which grow very slowly in this upland country, have not had time to establish themselves on the lower and last uncovered part of the valley, and have only begun to occupy the earlier drained upper half.

STRUCTURE.

McKay,* in his classic study of the structure of New Zealand, described two great fracture-lines as passing through the Mount Arthur district, one

* A. MCKAY, On the Geology of Marlborough and South-east Nelson, *Rep. Geol. Explor. during 1890–91*, No. 21, pp. 20–21, 1892.

on either side of the range. The fault-zone depressing the earth-block on the south-east side of the range is the Motueka fault, and that on the north-west side the Takaka-Karamea fault.

The former zone passes through the south-east corner of the area here mapped where the main fractures appear to strike about north-east. The physiography suggests that this course is maintained northward to the mouth of Motueka River, beyond which the zone has a direction more nearly north. Southward the fault-zone extends into the basin of Baton River, where, according to McKay, the Tertiary beds are deeply involved among older rocks. In this locality the large south-eastern downthrow of the fracture-zone decreases, or, rather, has been transferred to another great fault-zone that joins the Motueka fault in the lower valley of the Baton, and, striking a little west of south, extends along the foot of the mountains in the valleys of the Sherry, upper Tadmor, and Hope streams. This is Morgan's Hope fault.*

FIG. 3.—Fault scarp along the western flank of the Pikikiruna Rngae, Lower Takaka Valley.

The Takaka-Karamea fault-zone extends north-eastward diagonally through the district. It extends south-westward along the Leslie and upper Karamea rivers, its course being marked by a strip of Tertiary rocks that have been protected from denudation by depression. North-eastward one important fracture of the zone passes into the headwaters of the Riwaka River between Hoary Head (4,780 ft.), the most northerly peak of the Mount Arthur Range, and Haile's Knob (4,205 ft.), the most southerly peak of the Pikikiruna Mountains, the range along the east side of the Lower Takaka Valley. The other fractures either turn to a more northerly direction or die out, their westerly downthrow being transferred to the fault-zone, striking nearly north and south, along the western base of the Pikikiruna Range.

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* P. G. MORGAN, Supposed Coal-measures, Lamb Valley, near Glenhope, *N.Z. Geol. Surv. 15th Ann. Rep.*, C.–2c, p. 26, 1921. (See also *N.Z. Geol. Surv. Bull. No. 22*, p. 177, 1919.)

When these great fractures were formed, probably at the close of the Tertiary, the area now occupied by New Zealand was a low-lying land-surface or a shallow sea-bottom. The earth's crust, broken into great blocks, was elevated to form the rough outline of the Dominion as it now is. The mountain-ranges represent elongated groups of earth-blocks elevated to a greater extent than others. Erosion has greatly modified their original shape, of which, however, in a few localities the outline may still be distinguished. The Tableland is a tilted block dissected by streams. It was part of the old sea-bottom reduced to an even surface (finally by waves), and covered with marine deposits. Remnants of these Tertiary marine beds, not yet removed, occur on the Tableland, chiefly along the fault-angle at the base of Mount Arthur Range; but for the most part the slope, where not destroyed, is the stripped surface of the pre-Tertiary rocks.

The western edge of the tilted block seems to lie a little west of the Peel-Iron Hill-Lockett line of peaks, east of which the remnants of the sloping surface can readily be traced to the flanks of the Mount Arthur and Pikikiruna ranges. The fall, in ten miles, is from about 5,500 ft. to

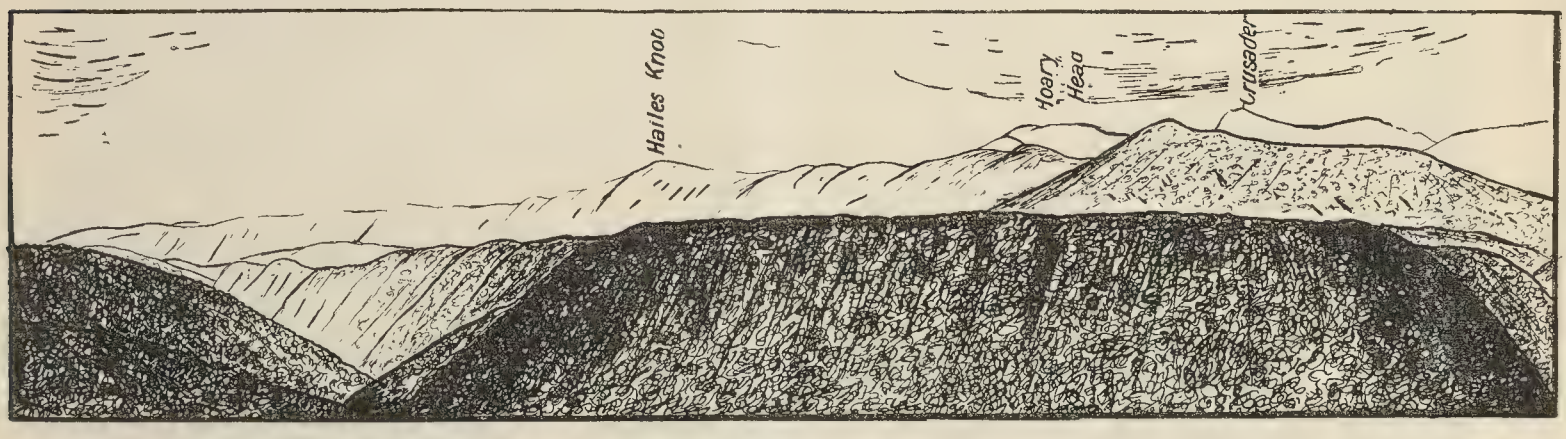

FIG. 4.—Takaka Valley from asbestos claim.

about 2,000 ft. From a distant aspect the tilted block is seen to extend for miles north of the district here considered. In this direction its eastern edge, abutting against the Pikikiruna Range, seems to sag downward, so that the fault-angle near Upper Takaka Post-office is replaced by a narrow trough. Two or three miles farther north this trough is wider, where part of the earth-block to the west is depressed along a north-west-striking fault.

Though the western edge of the tilted block is not marked by a physiographically prominent zone of displacement, a fracture of some kind probably occurs. The southern end of this break is thought to traverse the deep valley of Peel River. From the edge of the Mount Arthur Tableland a great tectonic depression is seen to extend south-west beyond the Peel, along the Leslie and upper Karamea valleys. An earth-block tilted to the south-east rises from the flank of the Mount Arthur Range, and in or near the fault-angle so formed flow the streams above mentioned. The tilted block was probably once covered with Tertiary strata, which is for the most part now removed. Remnants form an irregular fringe along the trough of the fault-angle, and a large patch above the bush-line rests on the mountains south-west of the Leslie-Karamea junction. The planed surface of the ancient rocks is now in great part destroyed, but is indicated by the long spurs that descend, with gently sloping crests, to the Leslie Valley from the highlands on its north-west side.

GENERAL GEOLOGY.

The present examination was insufficient to allow of a coherent account of the geology of the Mount Arthur district being given, and the following notes are largely supplemented from the reports of other geologists.

The Mount Arthur Range and Tableland consist for the most part of ancient sediments that have been folded and metamorphosed and intruded by large masses of acid, basic, and ultrabasic igneous rocks. McKay has divided these old sedimentary strata into three series, ranging in age from the Lower Silurian to the Upper Devonian.

Mount Arthur Series.

The oldest group of rocks, the Mount Arthur Series of McKay,* consists, according to that geologist, of the following beds, arranged in ascending order: (*a*) White crystalline limestone (marble); (*b*) blue slate found in the southern part of area examined by McKay, but not in the Mount Arthur district, where quartzites occupy an equivalent position; (*c*) grey and blue subcrystalline limestones (marbles) which pass upward and laterally into dark carbonaceous slates (phyllites). The only section of the rocks of this series examined by the writer is that exposed along the Graham–Flora track. Massive light-coloured and coarse-grained marble, in places intruded by granitic rocks, outcrops for about a mile along the south side of the Graham. It dips steeply up-stream, and appears to pass under the quartzites and quartz-schists exposed near Thorn's Hut. Near this point a fault may cross the valley, beyond which dark-coloured marbles and calcareous schists outcrop to the saddle between the Graham and Pearce streams. The structure is decidedly irregular. Between the Graham–Pearce and the Pearce–Flora saddles are calcareous schists and phyllites, in places much broken. For more than a mile down the Flora exposures are poor; down-stream from Quartz Creek occur carbonaceous schists and dark phyllites, near Horseshoe Creek, containing bands of dark marble. At this stream subschistose greywackes and argillites, probably belonging to a younger formation, appear. According to McKay, the schists and phyllites west from the Flora saddle pass laterally into the great mass of grey and dark marble forming the Mount Arthur massif. Northward dark phyllites occur toward the heads of Ghost and Baron creeks. The Crusader and Hoary Head, peaks of the Mount Arthur Range, are formed of marble, which extends northward into the headwaters of the Riwaka,† where it dips beneath schists and quartzites. On the west side of the Takaka Valley, near the New Zealand Marble Company's quarries, about ten miles north of the district mapped, marble overlies and is interbedded with feldspathic mica-schist.

Aorere Series.

According to McKay,‡ the rocks of the Mount Arthur Series are unconformably succeeded by "blue slates" of "considerable thickness," which pass upward into calcareous fossiliferous beds. The whole forms his Baton River Series, which he mapped as confined to the basins of the Baton and Wangapeka rivers. Above the junction of the Dart with the Wangapeka,

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* A. McKAY, The Baton River and Wangapeka Districts and Mount Arthur Range, *Rep. Geol. Explor. during 1878–79*, No. 12, pp. 123–25, 1879.

† *N.Z. Jour. Sci. & Tech.*, vol. 1, p. 175, 1918.

‡ *Op. cit.*, p. 125.

Park* found that the calcareous fossiliferous slates were overlain conformably by hard grey cherts and cherty sandstone. Park's Baton Series of a later report† consist of quartz-schists, quartzites, and feldspathic sandstones overlying grey, blue, and black slates, these last-mentioned forming the original Aorere Series of Cox,‡ which contain fossils indicating an Ordovician age. This, the Aorere Series, has been traced in the West Coast southward as far as Ross (see *N.Z.G.S. Bulls. Nos. 11, 17, 18, 13,* and *6*). Evidently the fossiliferous calcareous beds of the Baton River pass upward into cherty sandstones which in the western part of the Collingwood district are represented by quartzites and feldspathic sandstones. The blue slates underlying the fossiliferous beds of the Baton are presumably the equivalents of the Aorere Series, which, in its typical locality, consists of alternations of argillite and greywacke.

Beds believed to belong to the Aorere Series are exposed at the Flora-Takaka junction, whence they extend up-stream along the Flora for three-quarters of a mile, and up and down the Takaka for similar distances. They strike, for the most part, about east and west, and dip southward at about 50°. They consist of argillites and greywackes indistinguishable lithologically from the Aorere rocks of the West Coast. They contain quartz veins and numerous intrusions of basic rock.

Similar argillites and greywackes outcrop for about three miles along the lower part of the track from the Tableland to the Leslie River, and extend up-stream to at least as far as the confluence of Arthur Creek.

Baton River Series.

The rocks on the edge of the Tableland overlooking the Peel Valley are quartzites dipping eastward at a small angle. Down the Tableland–Leslie track for 1,000 ft. below the plateau the rocks exposed are chiefly quartzites and siliceous greywackes and argillites with thin bands of dark impure limestone. Though no fossils were observed, these beds are thought to be the equivalents of the upper part of McKay's Baton River Series, which, from their fossil content, are known to be of Upper Silurian age.

The quartzites on the edge of the Tableland extend north and north-east from Trig. H, and apparently occupy a considerable area in this locality. Close to the north boundary of the district quartzites and quartzose schists referred to this series occur on the ridge between the Cobb and Takaka rivers, whence they extend along the east side of the Takaka to Grecian Creek. The quartzites overlying subschistose greywackes in contact with masses of basic igneous rock exposed along the track in the valley of Ghost Creek are a continuation of these beds.

Haupiri (or Te Anau) Series.

The rocks of this series consist of conglomerates, breccia conglomerates, greywackes, and argillites. The greywackes, which also constitute the matrix of the conglomerates, differ lithologically from those of the Aorere Series. They seem on the whole to be coarser in grain, to contain less

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* J. PARK, On the Geology of the Owen and Wangapeka Goldfields, *Rep. Geol. Explor. during 1887–88*, No. 19, pp. 81–82, 1888.

† J. PARK, On the Geology of Collingwood County, Nelson, *Rep. Geol. Explor. during 1888–89*, No. 20, pp. 234–36, 1890.

‡ For a discussion of the use and misuse of the term "Aorere Series" see *N.Z.G.S. Bull. No. 25*, pp. 18–19, 1923.

argillaceous matter, and to weather more readily. The argillites are more siliceous than the corresponding rocks of the Aorere Series, and have a more fissile structure.

The contact of the Haupiri Series with the underlying beds was not observed, but that it is an unconformable one is shown by the occurrence of pebbles of quartzite, quartzose greywacke, argillite, and (near Lake Peel) siliceous marble in the conglomerate. Although conglomerate bands occur near the base of the series, the lower part of the Haupiri beds is chiefly rather coarse quartzose greywackes with minor bands of argillite and quartzite. The rocks contain no fossils, and it is on account of their unconformably overlying the Baton River Series and underlying the Maitai Series that they were classed as Upper Devonian by the old Geological Survey.

Gordon's Pyramid is formed of Haupiri rocks, the lower beds being exposed between Horseshoe and Gridiron creeks, the more typical conglomerates forming the mass of the mountain. According to McKay,* the Mount Arthur Range south of the Mount Arthur massif consists of these rocks, which Park† shows as extending without break to the heads of the Karamea, Wangapeka, and Mokihinui rivers. On the Tableland track they appear south-west of the basic igneous rocks, and extend nearly to the western edge of the plateau. They occupy large areas of the Tableland, and cross the Cobb Valley to Iron Hill and Mount Lockett, whence they extend to Boulder Lake‡ and into the Parapara districts.§ Much of Mount Peel consists of the conglomerates characteristic of this formation, but the main ridge is of fine greywacke or argillite split into platy fragments by the frost, and doubtfully included in the Haupiri Series.

Tertiary Series.

A strip of Tertiary limestone extends along the south-east side of Leslie River from its junction with the Karamea to the Mount Arthur Tableland, along the south-east edge of which the same rocks occur in patches almost continuously. Other small patches lie on the Tableland west of the Takaka River, some on its western edge protected from denudation through being faulted about 150 ft. below the general level, and other larger patches immediately north of Deep Creek. The rocks are usually sandy limestones, consisting chiefly of broken fragments of shells and polyzoa, and containing near their base bands of smoothly rounded quartz pebbles. Similar pebbles were observed scattered on the surface at several points on the Tableland where no limestone is now present, as along Starvation Ridge, at the foot of Balloon Hill, and on the ridge between the Takaka and Cobb rivers north-west of the asbestos claim. Evidently Tertiary rocks, at one time, covered a larger part of the Tableland than they now do.

In the Leslie Valley the limestone is at least 300 ft. thick, but elsewhere is decidedly less. Overlying beds were nowhere observed. Generally the limestone rests directly on a surface of truncated old rocks; in places sands and quartz grits or conglomerates a few feet thick occur; and on Cedar Flat, along the track to Upper Takaka, perhaps 50 ft. of sandy glauconitic mudstone intervenes.

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* *Op. cit.*, p. 127.
† *Op. cit.*, p. 237.
‡ *Idem.*
§ *N.Z.G.S. Bull. No. 3*, p. 45, 1907.

For the most part the Tertiary beds lie flat or dip gently, but in places where they abut against the Mount Arthur Range they dip steeply along the faults, as on the west flank of Gordon's Pyramid and in the upper valley of Ghost Creek.

A few fossils were collected from the limestone, here of high grade, that covers Cedar Flat. These were *Pecten burnetti*, *P. hutchinsoni*, and brachiopods.

Granite.

Granite outcrops along the lower valley of Graham Stream, where it appears to be separated from the marble by a large fault. West of this fault granite extends along the valley of the Graham, and on the track is seen to intrude the marble. These acidic rocks are part of the great belt that extends continuously along the eastern edge of the highlands, northward to Separation Point and southward to Lakes Rotoroa and Rotoiti.

The age of the granite cannot be precisely fixed. It intrudes, and is therefore younger than rocks of the Mount Arthur Series, which belong to a period older than the Ordovician. On the other hand, the conglomerates at the base of the Triassic beds of the Nelson District contain a variety of acidic igneous rocks* derived from an adjacent land-surface exposing granite, which may well have been part of the mass now outcropping. The conglomerates and breccias of the Haupiri Series also contain pebbles of igneous rocks,† usually in small amount; but as far as the hurried observations made on the present occasion are concerned, these pebbles, which occur abundantly in the conglomerates forming Balloon Hill, are much silicified and appear to have originally been of basic composition.

Basic and Ultrabasic Igneous Rocks.

Small exposures of basic igneous rocks, which from field observations appeared to be of diorite or quartz gabbro, were observed on the Graham track associated with the granitic rocks that there intrude the marble. McKay‡ and Park§ show these outcrops as part of a belt of basic igneous rock that extends for many miles north and south along the eastern edge of the highlands. An analysis of a basic rock outcropping in the Riwaka Valley and belonging to this belt is given in the *N.Z. Journal of Science and Technology*, vol. 1, p. 177, 1918.

The largest exposures of basic and ultrabasic rocks in the district appear in the valley of the Takaka River about four miles north of Mount Arthur, and extend to the north boundary as a continuous belt varying up to a mile and a half in width. Similar rocks occur in the Parapara district, fifteen miles to the north, and probably cover large areas in the intervening rough mountainous country of the Waingaro and Anatoki basins. Farther south, in the Upper Takaka Valley, are numerous basic dykes, some of large size. These are no doubt connected with the masses of rock exposed in the upper valley of Hodge Creek, on the west flank of Gordon's Pyramid, and on the Tableland near "the Caves." Another area of coarse-grained basic intrusive rock occurs south of Cobb Valley, about two miles east of Mount Peel. Basic rocks are also reported to

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* P. MARSHALL, Boulders in Triassic Conglomerate, Nelson, *Trans. N.Z. Inst.*, vol. 36, pp. 467–71, 1904.

† A. MCKAY, *op. cit.*, p. 127, and *N.Z.G.S. Bull. No. 3*, p. 46, 1907.

‡ *Op. cit.*, pp. 124–25.

§ *Op. cit.*, pp. 233–34.

outcrop in the watershed of Graham Stream on the ridge two miles south-east of the Loadstone.

So far as examined, pyroxenites, in part altered to serpentine, are the principal rocks of the largest mass of basic igneous material of the district. Pyroxenite also forms the outcrops two miles east of Mount Peel, near the Caves, on the north flank of Gordon's Pyramid, and about Hodge Creek. Gabbros, not containing olivine, occur in Ghost Creek and about Bullock Creek. Fine-grained basic rocks, now greatly altered, occur beside the track at various points between the Takaka and Flora bridges, and at several points on the track to the Tableland for half a mile above the Flora junction. These rocks are intrusive into the Palaeozoic argillites and greywackes. A coarser-grained much-altered basic rock, probably a dolerite (diabase), outcrops on the track a few chains west of Gridiron Creek.

The pyroxenites seem everywhere to be more or less serpentinized. The fresh-looking rock at the bridge across the Takaka (No. 1 of the accompanying table), selected for analysis, has evidently been somewhat altered. This rock consists chiefly of rounded grains of enstatite with a much smaller amount of diallage. The structure is poikilitic. The enstatite in places is intergrown with diallage, and the diallage with enstatite. Diallage is more abundant in the rock from two miles east of Mount Peel and from Hodge Creek.

Two types of serpentine are readily distinguished in the field. One stands up in rugged rough-surfaced dark-brown masses. When broken the rock is dark and dense, with $\frac{1}{2}$ in. or less weathered to a reddish-brown tint. The rock is divided into large irregular blocks of massive serpentine by thin irregular streaks of crushed material, which weather out to a depth of several feet and produce the rugged outcrop of this type of serpentine. The surface of the other type is rounded, is usually covered with vegetation, and, where exposed, weathers to a yellowish or greenish white. When broken it is softer and more uneven in colour and texture. The bulk of it is dark grey flecked with green, and in thin flakes is more or less translucent in green tones; some is light yellowish-green, and some is mottled with dark spots on a light-green ground. Much of the second type of serpentine consists of closely packed flakes with polished surfaces, and has evidently been subjected to pressure and movement. Scattered through this flaky material are rounded masses varying from 1 ft. in diameter upward. The amount of flaky material varies greatly: in some places it constitutes almost the whole of the rock; in other places there is a minimal amount between the rounded masses, which are more irregular in shape and decidedly larger, as much as 10 ft. in maximum diameter. This structure then approaches that of the first type of serpentine.

In the few sections of the first type of serpentine examined under the microscope the rock consisted of a dense mass of antigorite blades, many of them arranged nearly at right angles to one another, by which a grated appearance is produced. Grains of iron-ore are abundant, and their arrangement suggests that bastite was once present.

The second type of serpentine is much more variable. The centres of the larger rounded masses are dark-coloured, and under the microscope are seen to consist chiefly of bastite, altered from rounded grains of enstatite, with a small amount of antigorite. The periphery of the rounded "boulders" is translucent, rich oil-green in colour, massive in texture, and contains numerous veins of chrysotile. The intermediate portions of the

" boulders " is light-coloured, massive-textured serpentine flecked with dark spots of bastite, and also containing numerous veins of chrysotile. The slickensided flaky rock between the " boulders " seems to consist chiefly of an aggregate of antigorite containing small veins and irregularly distributed fibres of chrysotile. Analyses are given in the table of dark bastite serpentine (No. 3), light-coloured serpentine (No. 4), chrysotile (No. 6), and bowenite (No. 5), which is a variety of massive granular serpentine much resembling nephrite. Bowenite was observed at several points in the asbestos claim. Picrolite and metaxite also occur.

At two points the serpentine toward the centre of large " boulders " passes into a dense, heavy, almost white rock flecked with green. Under the microscope it is seen to consist of flakes of bastite and diallage, granular aggregates of grossularite garnet, and irregular crystals of unaltered augite (diopside). Veins of prehnite occur, and small irregular areas of antigorite (No. 9 of table).

One sample of dark, dense rock was collected that shows the mesh structure typical of serpentines derived from olivine rock, but the precise nature of the original rock was not ascertained.

A band of talc-carbonate rock, altered from serpentine, extends from across the Cobb Valley southward more or less continuously to the asbestos claim. It varies up to several chains in width, and consists essentially of talc associated with carbonates of calcium, magnesium, and iron. In places the whole width of the band seems to be of talc, and in others of carbonates. Other similar but less continuous bands occur in other parts of the area, most of them at or close to the edge of masses of serpentine.

The gabbro, of which the analysis is given in the table (No. 10), is seen under the microscope to consist of aggregates of pale-green hornblende (? actinolite) prisms replacing the original ferromagnesian mineral. The feldspar, which was moulded round the ferromagnesian, is completely saussuritized.

The dolerite (diabase) outcropping on the track near Gridiron Creek is also greatly altered. The ferromagnesian minerals are now represented by aggregates of carbonates, probably dolomite or ankerite; the feldspars, though decidedly cloudy, still show twin lamellae, and are enclosed in the ferromagnesians with typical ophitic structure. Patches of serpentinous and chloritic material also occur. In parts this rock is still decidedly altered and passes into a talc-carbonate rock.

The dense, dark rock outcropping on the Tableland track at several localities within a mile of the Flora junction and between that point and the bridge across the Takaka consists essentially of a fine-grained aggregate of granular carbonates, decomposed feldspar-grains, and serpentinous and chloritic material. The rock, of which No. 11 is an analysis, is probably an altered dolerite.

Numerous loose fragments of a light-coloured greenish porphyritic rock occur along the track to Upper Takaka, west from Ghost Creek crossing. This rock, under the microscope, is seen to be an augite porphyrite, phenocrysts of basic feldspar and of augite, now in great part altered to serpentine, occurring in a fine-grained much-decomposed groundmass.

A dyke of fresh basalt about 2 ft. thick penetrates granular pyroxenite occurring about the middle of the claim on the north side of Asbestos Creek. It consists of a fine-grained matrix of grains of feldspar, augite, and olivine containing feldspar-lathes and skeleton crystals of iron-ore. An analysis of this rock is given in the table (No. 12).

Table of Rock-analyses.

—	1.	2.	3.	4.	5.	6	7.	8.	9.	10.	11.	12.
Silica (SiO_2)	51·67	53·55	48·94	40·01	40·72	41·97	39·54	39·05	43·09	48·53	49·95	41·09
Alumina (Al_2O_3)	4·56	1·53	2·03	1·99	0·64	1·13	None	3·67	8·61	16·46	9·82	14·13
Ferric oxide (Fe_2O_3)	0·66	0·53	1·09	2·39	2·77	1·14	1·35	2·41	0·44	1·29	0·86	2·49
Ferrous oxide (FeO)	6·82	4·27	5·52	0·58	0·80	0·63	0·16		4·24	6·22	7·59	12·44
Magnesia (MgO)	22·04	35·01	25·94	38·91	40·35	40·53	39·89	40·07	21·91	9·61	12·62	7·20
Lime (CaO)	9·09	1·79	8·85	None	0·05	0·04	1·38	..	14·06	12·28	6·75	11·00
Potash (K_2O)	0·06	None	0·04	None	None	None	0·12	..	0·06	0·33	None	0·28
Soda (Na_2O)	0·14	None	0·02	None	None	None	0·54	..	None	1·24	None	1·64
Water above 105° C.	4·03	2·26	6·04	13·11	12·88	12·59	15·58	14·48	5·61	3·35	6·05	4·26
Water below 105° C.	0·45	0·14	0·52	2·09	1·32	2·13	1·80	..	0·78	0·46	0·72	0·76
Carbon dioxide (CO_2)	None	None	None	None	None	None	..	..	None	0·07	5·31	None.
Titanium dioxide (TiO_2)	0·05	0·17	0·04	0·03	0·03	0·04	None	..	0·32	0·11	0·12	3·60
Zirconium dioxide (ZrO_2)	None	..	None	None	None	None	..	..	None	None	None	None.
Phosphorus pentoxide (P_2O_5)	0·05	..	0·06	0·07	0·06	None	..	..	Trace	0·05	0·03	0·78
Sulphur (S)	None	..	Trace	Trace	Trace	Trace	..	..	None	Trace	None	Trace.
Chromium trioxide (Cr_2O_3)	0·29	0·42	0·44	0·48	0·16	None	..	..	0·33	0·02	0·12	0·02
Manganous oxide (MnO)	0·06	0·12	0·20	0·03	0·12	0·07	0·17	..	0·31	0·13	0·04	0·05
Nichel oxide (NiO)	0·08	Trace	0·09	0·08	0·09	0·13	..	..	0·12	0·05	0·15	0·27
Baryta (BaO)	None	None	None	None	None	None	..	..	None	None	None	None.
Strontia (SrO)	None	..	None	None	None	None	..	..	None	None	None	None.
	100·05	99·89	99·82	99·77	99·99	100·40	100·53	99·68	99·88	100·20	100·13	100·01

(1.) Enstatite-diallage rock (pyroxenite), Takaka Bridge. Analyst, F. T. Seelye.
(2.) Enstatite rock. W. N. Benson, "The Geology of the Great Serpentine Belt of New South Wales," *Proc. Lin. Soc. N.S.W.*, vol. 38, p. 705. 1914. Analyst, W. N. Benson.
(3.) Dark-coloured bastite serpentine, asbestos claim. Analyst, F. T. Seelye.
(4.) Light-coloured serpentine, asbestos claim. Analyst, F. T. Seelye.
(5.) Bowenite, asbestos claim. Analyst, F. T. Seelye.
(6.) Chrysotile, asbestos claim. Analyst, F. T. Seelye.
(7.) Chrysotile, Lionel, West Australia. Report of the Department of Mines for 1921, West Australia, p. 109, 1922. Analyst, H. Bowley.
(8.) Chrysotile, Thetford, Canada. F. Cirkel, "Chrysotile-asbestos," *Bull. No. 69*, Canada Department of Mines, p. 31, 1910.
(9.) Grossularite rock, asbestos claim. Analyst, F. T. Seelye.
(10.) Gabbro, 40 chains north of Takaka Bridge. Analyst, F. T. Seelye.
(11.) Fine-grained basic rock, 30 chains south of Takaka Bridge. Analyst, F. T. Seelye.
(12.) Basalt, dyke in enstatite-diallage rock, asbestos claim. Analyst, F. T. Seelye.

ECONOMIC GEOLOGY.

Of the economic deposits of the district the auriferous gravels have hitherto received by far the most attention, and of those workable at a profit the greater part seems now to have been sluiced. Platinum also occurs in small amount in the gravels. Quartz lodes containing gold and various other metals are known to traverse the older rock series and the serpentinous rocks, but so far none has been found payably auriferous. Several excellent building-stones occur in large quantity. The most valuable mineral deposits, however, are those of asbestos and talc occurring in connection with the serpentines of the district.

Alluvial Gold.

The principal workings in the district were on the Tableland. Its surface, where the Tertiary rocks have been removed, is covered with a few feet of soil and of rock-fragments weathered from the underlying beds. Patches of this broken rock containing alluvial gold in payable amount are irregularly distributed. Smoothly rounded pieces of quartz up to 6 in. in diameter, but usually less than 1 in., occur with the broken rock. The Tertiary rocks contain similar pebbles, and, since they occur most numerously close to the remaining patches of Tertiary strata, they are thought to have been derived from the once widespread sheet of these beds. Throughout the western portion of Nelson the conglomerates and quartz grits that generally form the basal Tertiary beds contain detrital gold at many points. These beds accumulated on a gradually sinking shore as beach deposits in which the gold was laid down in leads just as on present-day beaches. McKay* collected from near the base of the Tertiary beds of the Mount Arthur district specimens of gritty limestone containing detrital gold. Since the ancient gold-bearing beach-leads were irregularly distributed, it follows that the patches of auriferous wash are also irregular. The most important of these workings was known as the Balloon Diggings, which occur in the extreme headwater branch of Takaka River. Here the gold is present in loose, angular and subangular detritus about 2 ft. thick, and derived by weathering from the underlying greywacke. Very few rounded pebbles of quartz were observed. The bulk of the gold was obtained from the bed of Balloon Creek and its branches. But patches on the gently sloping surface many square chains in area have been stripped of soil and subsoil; narrow gutters traversing these patches and descending from them to the streams have been cleaned out and deepened, since the gold, it is stated, was found in payable amount in joint-planes and cracks as much as 5 ft. below the rock-surface.

At Cundy's Creek, rather less than a mile south of the Balloon Diggings, the gold was found in wash formed chiefly of small, smoothly rounded quartz pebbles. Patches of gritty limestone containing similar pebbles occur in the immediate neighbourhood. At the Caves, about two miles south-east of the Balloon Diggings, the wash is clayey and was puddled. Here the streams flow to the Leslie River by way of underground channels through the limestone. Several other less important groups of old workings occur on the Tableland, but were not visited.

The larger streams, which are deeply incised in the Tableland, also contain gold, and patches of ordinary stream-wash have been worked at

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* A. MCKAY, The Baton River and Wangapeka Districts and the Mount Arthur Range, *Rep. Geol. Explor. during 1878–79*, No. 12, p. 130, 1879.

many points. The larger streams so worked are the Leslie and its branch Arthur Creek, the Takaka and its tributaries, the Flora, Grecian, and Waitui streams. Several of the smaller creeks also contain auriferous wash—namely, Heath, Mataki, Hodge, and Gridiron creeks. The bulk of the gold in all of these was certainly derived from Tertiary beds, although quartz lodes and veins are known to occur in the basins of several, and in Gridiron Creek have been prospected.

Platinum.

From time to time samples containing platinum have been forwarded to the Dominion Analyst from the Mount Arthur district. Hochstetter in 1859 had observed the presence of grains of the platinum metals with the gold won from the gravels of Takaka River. That the grains are derived from the masses of ultrabasic rock in its upper basin is suggested by the fact that they occur much more abundantly below the crossing of the main mass of basic igneous rocks than above it.

Quartz Lodes.

Quartz lodes and veins occur in the Palaeozoic rocks at numerous points. They outcrop on the track in the upper Graham and Flora valleys, where they traverse the calcareous schists and black phyllites of the Mount Arthur Series. The veins are most abundant in the Flora Valley, near the junction of Quartz Creek, from which locality they extend northward toward the Loadstone. The greywackes and argillites exposed near the Flora-Takaka junction contain several irregular lodes as well as veinlets of barren-looking quartz. Near the Ghost Creek crossing on the track to Takaka a large quartz lode outcrops in rocks thought to belong to the Baton River Series. The greywackes and conglomerates of the Haupiri Series also contain quartz veins. They were observed in these rocks on Mount Peel, and have been extensively prospected on Gordon's Pyramid. Others are stated to outcrop on the north-west face of the Mount Arthur Range. According to Cox,* who examined them in 1879, the quartz veins of Gordon's Pyramid consist of a series of leaders separated by hard gritty sandstone. They strike about north-east and dip south-east. In addition to gold, the quartz in places contains much iron-pyrites as well as other sulphides—pyrrhotite, galena, zinc-blende and copper-pyrites.

A quartz lode varying up to $2\frac{1}{2}$ ft. thick occurs on the north side of Cobb River in the talc-carbonate band traversing the serpentine mass. A sample examined in the Waihi School of Mines was found to contain 2 dwt. 15 gr. of gold and 5 oz. 16 dwt. 4 gr. of silver per ton. A large amount of metallic minerals is present, as the following analysis, made in the Waihi School of Mines, shows :—

Iron	11·1
Copper	3·9
Antimony	1·7
Lead	0·8
Zinc	1·2
Silica	57·0
Sulphur and undetermined	24·3
	100·0

* S. H. Cox, The Mount Arthur Reef, *Rep. Geol. Explor. during 1879–80*, No. 13, p. 9, 1881.

These constituents are probably combined as—

Iron-pyrites (FeS_2)	24·0
Tetrahedrite ($4Cu_2S.Sb_2S_3$)	7·0
Malachite ($CuCO_3.CuH_2O_2$)	0·3
Galena (PbS)	0·9
Zinc-blende (ZnS)	1·8
Silica (SiO_2)	57·0
Undetermined	9·0
	100·0

McKay* long ago reported the presence of large irregular masses of iron-ore associated with the fine-grained breccias and blue limestones (marble) west of Mount Peel. He collected samples containing 54 per cent. of metallic iron from where the beds were 50 ft. thick. Isolated irregular masses 10 ft. to 15 ft. across were stated also to be present in this locality. North of Takaka River (by which McKay obviously misnames the Cobb) much larger deposits (presumably Iron Hill) of iron-ore were reported by diggers to occur.

The writer saw no large deposits of iron-ore. The fine-grained greywackes forming the long ridge of Mount Peel are much stained by hydrated oxides of iron, and in places small quantities of high-grade ore occur. Iron Hill was not visited, but extensive slopes of red-stained broken rock occur near its summit, which consists of great irregular masses of rock (or ore).

Asbestos.

An account† of the asbestos deposits of the Mount Arthur district has already been published, and nothing can be added to it except the analysis of Mount Arthur asbestos given in the table of analysis (No. 6). The Dominion Analyst also reports that fibres of chrysotile from the claim embedded in fireclay and heated in a crucible in a coke-furnace to a temperature of 1,530° C. showed no sign of fusion, though the colour had changed to a pale-yellowish shade. Fibres readily fuse in the blowpipe flame.

Talc.

Talc occurs in large amount in the district, for the most part in connection with the talc-carbonate bands that traverse and probably replace the serpentine. Talc unassociated with carbonate and contaminated with only a small proportion of serpentine or other rock occurs immediately below the junction of Ghost Creek with Grecian Creek, near where the track to Upper Takaka crosses the south branch of Ghost Creek, and on the track from the bridge across the Takaka to and about a mile from the asbestos claim. In Grecian Creek the talc is exposed for about 4 chains, and on the track from the bridge to the creek for at least a chain. In both localities it occurs in massive form.

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* *Colonial Museum and Laboratory 14th Ann Rep.*, pp. 32–34, 1879.

† J. HENDERSON, Chrysotile Asbestos in the Upper Takaka District, *N.Z. Jour. Sci. & Tech.*, vol. 6, pp. 120–23, 1923.

NATURAL-HISTORY NOTES.

Note on a Worm found in the Same Shell as a Hermit-crab, by Maxwell W. Young, F.C.S., Biologist, Portobello Marine Hatchery and Biological Station, Dunedin.

In 1921 a hermit-crab (*Eupagurus edwardsi*) under observation in one of the tanks at the Portobello Hatchery was noticed to have as a companion in its shell a large worm. I left the strangely assorted couple alone for some months to see if the relationship would continue, and the effects, if any, on the crab. In December the worm was removed and sent to Dr. Benham, of the Otago University Museum, for identification, and he pronounced it to be a specimen of *Chilonereis peristomalis* Benham. The specimen was 16 mm. long when removed for examination. The crab was still in a healthy condition at the time of removal of the worm, so it has evidently been a case of commensalism. Companionships of this kind between Annelids and Paguridae have been noted from the Northern Hemisphere,* but are comparatively rare in our waters. This is the only case I have observed since 1921; and, as all the hermit-crabs brought up in the trawl have been examined very carefully since then, with negative results, I consider this occurrence is of sufficient rarity here to be worth recording.

Australian Native Hen, by Professor W. B. Benham, F.R.S.

It may be well to put on record the occurrence in Southland of a specimen of the Australian black-tailed native hen, or "moor hen" (*Microtribonyx ventralis*). The bird was shot by Mr. Cook at Oraki, near Colac Bay, in June this year, and forwarded to the Otago University Museum for identification and preservation. As the bird is said by Gould to be a feeble flier, and is generally rather rare and local, though in some years it occurs in great numbers in some localities, its arrival in New Zealand is of interest in relation to the dispersal of such birds. Though three specimens of the black Australian coot (*Fulica australis*) have been recorded, this is, I believe, the first time that the native hen has reached a museum.

REVIEWS AND ABSTRACTS.

Elementary Zoology, by OSWALD H. LATTER. Methuen and Co. (Limited), London, 1923.

With the advance in science and improved methods of instruction it is necessary that there should be good up-to-date text-books. Nowhere is this more important than in biology. The present work covers the subject of zoology to the standard prescribed in the University Matriculation

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* VAN BENEDIN, *International Science Series*, vol. 20, p. 42, 1876.

Examinations, the author being examiner in zoology for the University of London.

The method of presentation is, after some introductory remarks on living matter and the differences between animals and plants, to describe first the structure and physiology of mammals, the types selected for the purpose being man and rabbit. This portion occupies ninety-eight pages, or nearly one-third of the work. The remainder is devoted to a review of the phyla of animals in systematic order, beginning with the lowest and ending with the vertebrates. The last two chapters deal with colour in animals, evolution, and heredity.

In the systematic portion of the work the author has contented himself with describing a few types belonging to each phylum, or, in some cases, as with birds, treating the subject in a general way. The method of confining an account to types, while no doubt answering the requirements of the University syllabus, is not always sufficient to give the student a general idea of the phylum. For instance, the account of the Mollusca is confined to descriptions of the fresh-water mussel, sea mussel, and snail. No reference is made to the amphineura and cephalopods other than a sentence stating that the "class" of molluscs includes cuttlefish, squids, &c. Omissions such as these, however, are not to be attributed to the author but to the University syllabus, which requires a certain examination to be passed, and Mr. Latter has written his book in accordance with the syllabus.

The book is clearly written, with the headings printed in heavy type, is sufficiently illustrated by line drawings, and is to be commended to all students preparing for the University Matriculation Examinations.

A Manual of Histology, by V. H. MOTTRAM. Methuen and Co. (Limited), London.

For a clear and concise account of animal-tissues Professor Mottram's work leaves little to be desired. The work is written for the student of physiology and medicine, and describes the tissues of all the organs of the animal-body, and, as it is treated from the viewpoint of the physiologist, a certain amount of physiology is introduced. This greatly increases the usefulness of the work. The illustrations, of which there are 224, are an important feature of the book. These are large, clear line drawings, the work of the author, and many of them are whole-page diagrams. The author in his preface points out that the student requires a book with diagrams giving those features which he should look for under the microscope. The student, also, naturally draws in line, whereas text-books generally illustrate in various ways—line, half-tone, photomicrography, or lithography. Nor do they usually have high- and low-power views of all the tissues. This Professor Mottram has now given us. All tissues are illustrated by sections giving different views both under high and low powers. Thus the student gets clear illustrations of every tissue he is likely to meet with in the histology laboratory.

The book will undoubtedly be of very great assistance both to the student and teacher, and should be in the hands of all who are studying medicine. The work has entailed a great deal of care and patience on the part of the author, especially in the preparation of the illustrations. for which alone it is well worth obtaining. There is a useful appendix on methods of mounting and staining tissues.

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ON THE ABUNDANCE AND IMPORTANCE OF NON-LUMINOUS MATTER IN SPACE.

By A. C. GIFFORD, M.A., F.R.A.S., Wellington College Observatory.

NON-LUMINOUS matter in space can make its presence known to us only by the help of luminous matter. It is difficult, therefore, to estimate its quantity. Numerous indications, however, suggest that its total mass must exceed very greatly the mass of the visible universe. Observational proofs of its presence are continually accumulating, but even without these its presence might reasonably be inferred. On Earth we find luminosity a comparatively rare and transient attribute of matter. Most bodies emit light only whilst their temperature exceeds a certain limit. The amount of light given out by glow-worms and other cool bodies is an insignificant fraction of the total terrestrial light.

It is reasonable to suppose that physical laws are uniform throughout the universe. In distant space, therefore, as here on Earth, hot bodies tend to cool. Every wave of heat or light sent out from a radiant body carries away a fraction of its energy. Now, the total energy in any luminous star is a finite quantity, the amount due to gravitational contraction being easily calculated in the case of a star of known mass and size. If the subatomic energy is taken into account the quantity is very much greater and more indefinite, but still it cannot be infinite. Time, on the other hand, is unlimited. We cannot imagine a beginning or an end. If, then, any star was luminous an infinite time ago, it must long ere this have lost its luminosity unless its energy has been renewed. The existence of luminous bodies thus implies the existence of non-luminous ones, and suggests also that there must be some means of rejuvenation for them.

Non-luminous matter in space may make its presence known to us in any one or more of the following ways: (1) By obstructing the light of luminous bodies; (2) by reflecting the light of luminous bodies; (3) by causing changes in the motion of luminous bodies; or (4) by acquiring temporary luminosity.

It may exist in a great variety of different forms, such as dead stars, planets, satellites, cometary masses, meteoric swarms, very finely divided solid matter expelled from luminous bodies by the pressure of light, and cold gaseous bodies resembling the diffused nebulae. Vast systems comprising some or all of these various forms may exist also in distant space in a non-luminous state.

Let us glance first at some of the results of astronomical observation.

1. THE EVIDENCE OF THE OBSTRUCTION OF LIGHT.

Eclipsing Variables.—Since stars are so distant that they present no discs even in the greatest telescopes, it might have been thought hopeless to seek for instances of one star obstructing the light of another. This would doubtless have been the case but for the fact that many stars are physically connected into binaries and multiple systems. Chance eclipses of unconnected stars must almost always escape detection. It is only when stars are physically connected in such a way that eclipses recur at regular intervals that we are likely to notice them, and there can be no such eclipses unless the components of the pair or system are very close to one another or are revolving in a plane which passes almost through the Earth. It is very wonderful, therefore, that about a hundred and fifty such cases are already known, and we must infer that there are innumerable dark bodies whose presence cannot be shown in this way. The improbability of the planes of the orbits of all dark components of binary systems passing through the Earth is quite conclusive on this point.

"*Coal-sacks.*"—Dark patches in the Milky Way have been noticed from the earliest times, but it is only since the development of photography that their abundance and remarkable characteristics have been recognized. At first they were naturally considered to be "stellar deserts," or portions of space nearly or quite destitute of stars. The discovery of the immense size of the Galaxy made this hypothesis incredible. The extreme improbability of these dark markings being vacant holes in the stellar system became at once apparent when it was recognized that, to appear as they do, such cavities would have to be of the nature of straight hollow tubes extending through the Galaxy for distances of thousands of light-years, with every individual tube pointing directly towards the Earth.

In some cases these dark markings appear to have remarkably sharp and clear-cut margins. If they were vacant tubes in space they would, as Campbell pointed out, have been obliterated long ago by the invasion of hosts of the surrounding stars.

Not only their continued existence but their origin also presents insuperable objections to the "cavity" hypothesis. No method has been suggested in which such long empty tubular spaces piercing the Galaxy could have been formed.

That opinions with regard to the "Coal-sacks" and dark markings have changed greatly in recent years is shown by the following extracts :—

Eddington,* whilst giving reasons for believing that there is no considerable absorption of light in space, says :—

"Nevertheless there are large tracts of obscuring material in particular regions, which hide more or less completely the stars behind. These are found especially in the Milky Way, and consist of dark or faintly

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* *Encyclopaedia Britannica*, vol. 30 (1922), p. 301.

luminous nebulae often of great extent; perhaps there is no hard or fast division between them and the irregular gaseous nebulae like the Orion Nebula. A large obscuring tract in Taurus is estimated by A. Pannekoek to be at 140 parsecs distance; this may be compared with Kapteyn's value (190 parsecs) for the Orion Nebula. A catalogue of 182 dark markings in the sky has been given by E. E. Barnard."

In *The Observatory* (July, 1923), p. 232, the following note occurs:—

"In *Harvard Circular 242* Mr. S. I. Bailey makes a comparison of a Milky Way field with one at the pole of the Milky Way, and finds a startling increase in the ratio of the number of stars with increasing faintness. At the tenth magnitude the ratio is only 2 or 3, but at the seventeenth magnitude it is over 100. He makes also some interesting remarks on the probable existence of obscuring clouds as the principal cause of the apparent irregularities in structure. There has been a marked change in the attitude of astronomers towards this idea; Barnard himself, who latterly was an earnest advocate of obscuration, began by declaring that the dark patches were probably holes."

One of the most extraordinary of these dark nebulae is illustrated in the *Publications of the Lick Observatory*, plate ii, fig. 5. In a description of this region Curtis says:—

"But the most remarkable feature of the region is a dark bay which juts into and bifurcates I 434 at a point about 30′ S. of ζ Orionis. This is 5′ wide and 4′ deep, like an ink-blot except for a faint wisp in its northern portion, and as clear-cut and sharp as a knife-scratch on its western and southern edges—a beautiful example of a 'dark nebula.'"*

"Photographs and star-counts agree in showing a marked falling-off in the number of stars in the vicinity of the great diffuse nebulosities."† It is clear that this effect must be due to the presence of occulting and non-luminous matter outside the luminous portion of the nebula.

Dark spots and rifts are to be seen in many of the large diffused nebulae—for example, Messier 8. It is impossible to believe that these black spots are holes extending through the nebula for distances of several light-years. A much more reasonable explanation is that they are dark nebulae rendered visible by the bright background of the diffused nebula.

Campbell and Moore find evidence of absorptive material in the outer portions of certain planetary nebulae.

But by far the most striking examples of obstructing matter in distant space are afforded by the spiral nebulae. H. D. Curtis, in the *Publications of the Lick Observatory*, vol. 13, gives illustrations of seventy-seven spirals which show evidence of obstructing matter. The effect is most evident in those spirals which are seen edgewise. The photographs and descriptions given by Curtis are quite convincing as to the presence of an abundance of non-luminous matter in the outer portions of these remarkable systems. Dr. Curtis explains the peculiar grouping of the spiral nebulae themselves with regard to our Galaxy by supposing the latter to be a somewhat similar system with a great band of occulting matter, for the most part outside the visible periphery, which serves to cut off from our view the distant spirals lying near the projection of our galactic plane in space.

The fixed calcium lines in certain stellar spectra afford another proof of the wide distribution of invisible material. More than twenty spectro-

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*Page 23. †Page 49.

scopic binaries are known in the spectra of which the narrow K line of calcium remains stationary, whilst the other lines shift to and fro as the star approaches or recedes in its orbit. This shows that a mass of invisible calcium vapour surrounds each of the groups, or is situated somewhere in space between them and us.

Calcium is not the only element for which similar facts have been proved, for in the spectrum of δ Orionis the D_1 and D_2 lines of sodium are also "fixed."

2. DARK MATTER MADE APPARENT BY REFLECTING THE LIGHT OF LUMINOUS BODIES.

Our knowledge of the solar system is almost entirely dependent on the reflection of light. The Moon and most or all of the planets would be invisible to us without it. The fact that all these non-luminous bodies are found within the solar system—the only one near enough for us to see such bodies in—makes it exceedingly probable that similar dark bodies exist around the individual stars of the Galaxy, although the light they reflect is far too faint at this distance for any hope of its detection with the most powerful modern instruments. This belief is strengthened when we find that the encounter theory of the origin of the solar system applies also to the rejuvenation of stars, and involves naturally the formation of planets. (See paper to follow this on "The Formation of Planets during the Whirling Coalescence of Stars.")

The zodiacal light affords evidence of the existence of a lens-shaped mass of rarefied matter around the Sun, reflecting its light and symmetrically placed with respect to the ecliptic.

Reflected light is usually too weak to give us much information with regard to dark matter beyond the solar system; but non-luminous diffuse nebulosity may in some cases be rendered visible by reflecting the light of very brilliant stars. That round Merope and other stars in the Pleiades may by this means impress its record on the photographic plate.

3. DARK MATTER DETECTED BY ITS GRAVITATIONAL EFFECT ON THE MOTIONS OF LUMINOUS BODIES.

The discovery of the planet Neptune through perturbations which it caused in the orbit of Uranus is an excellent illustration of this method of proving the existence of unseen bodies; and we are justified in using it in this connection, since the planet, though appearing through the telescope by reflected sunlight as a star of the eighth or ninth magnitude, is far below the range of unaided vision.

Wonderful as this discovery was, it would not have appeared so inherently improbable as many of the achievements that are now accomplished as a matter of routine by the use of the spectroscope and the photographic plate.

Neptune, though on the outskirts of the solar system as at present known, and more than thirty times as far from the Sun as the Earth, is a very close neighbour to us compared with the nearest star. Yet the spectroscope tells us that large numbers of stars, which appear through the greatest telescopes with the highest magnifying-powers as single points of light, are in reality double suns revolving round one another in comparatively small orbits, in periods ranging from a few hours to several years. There are

now over six hundred such pairs known, and the list is being added to every year.

The details of many of these systems are most interesting. In Castor, for example, each bright component is a spectroscopic binary in which the companion is invisible. The period of one pair is nearly three days, that of the other over nine days; whilst the period of one binary about the other is about three hundred years.

Polaris was found to have a variable radial velocity, which was explained by it proving to be a spectroscopic binary with a period of nearly four days. The velocity of the centre of the mass of the visible system is, however, subject to slow variation. This indicates that the primary is attracted by, and is moving round, a third star which is invisible to us.

The existence of the faint companion of Sirius, which is about three-quarters of the Sun's mass, was disclosed by its gravitational effect twenty-eight years before it was seen by man, and its period of forty-nine years was predicted by Bessel to within a few months of what is believed now to be its true value.

The invisible companion of Mizar was the first to be discovered spectroscopically. The system is a remarkable one, as, besides the spectroscopic binary, there is a telescopic companion, and apparently connected with these there is the naked-eye star Alcor. It is estimated that if Alcor is revolving round the rest of the system its period is at least a million years.

Eddington* states that the radial velocities of 2,070 stars had been determined by 1921, and that 622 of these proved to be spectroscopic binaries. Allowing for systems of wider separation (not detected by varying radial velocity), the actual proportion of binaries must, he says, be still higher. It must be remembered also that it is only systems whose components are either specially near or very massive that are discovered in this way. The majority must for ever remain undetected. That so many spectroscopic binaries are already known affords convincing proof, therefore, of the existence of vast numbers of dark stars.

Many thousands of visual double stars are also known. Down to about the ninth magnitude one star in eighteen is found to be a visual double. We must believe that a similar proportion of the fainter stars would prove to be double or multiple if we were able to measure their radial velocities.

No observational method exists at present of proving the existence of single dark stars, unless by encounters with others they give rise to novae, in which case the evidence they afford comes under the next section.

4. THE EXISTENCE OF MATTER PREVIOUSLY NON-LUMINOUS PROVED BY ITS ACQUIRING TEMPORARY LUMINOSITY.

Meteors.—On any clear moonless night a single observer may notice within a few hours the flashes of several meteors (or, as they are misleadingly called, "shooting-stars"). The number to be seen varies very much from night to night, but it has been calculated that the average daily number which enter the Earth's atmosphere is not less than several milllons.

Most meteors are completely vaporized whilst passing through the air from a height of about eighty miles to that of fifty miles above the Earth's surface. Comparatively few, through being originally larger, reach the Earth before their dissipation is complete. Numbers have been found ranging in weight from a few ounces to several tons. The daily addition

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* *Encyclopaedia Britannica*, vol. 30, p. 297.

to the Earth's mass is probably less than 100 tons, but even this is a clear indication of the presence of an appreciable amount of dark matter within the solar system.

Comets afford still more striking evidence of dark matter widely spread. The average number of them discovered per year is about five or six, of which number one may become visible to the naked eye. Comets are often of enormous size. The head of the comet of 1811 was estimated to be 350 times the volume of Jupiter, and the length of its tail to be 100,000,000 miles. Considering their dimensions, the masses of comets are surprisingly small. They pass through the solar system without producing any measurable perturbations. Nevertheless the mass of a single comet may be measured in millions of tons, and, in the aggregate, existing comets must contain an important amount of matter. Their heads appear to be highly condensed meteoric swarms, and their tails extremely finely divided matter expelled from the heads by the radiation pressure of the Sun. The common fate of a comet is for the material of its head to be spread along the orbit until nothing remains of it but a chain of meteoric swarms.

The Earth has been enveloped more than once in the tail of a comet without any noticeable consequences, but we have no historical record of a collision between the head of one and the Earth. In Arizona, however, a cup-shaped crater, three-quarters of a mile wide and several hundred feet deep, around which many small meteorites have been found, seems to show that such an event has happened at least once in the past.

Since comets are only seen when near the Sun, and some pass far beyond the orbit of Neptune, they help to prove that non-luminous matter is widespread within the solar system.

Novae.—At stellar distances no transformation of dark into luminous matter can make itself known to us unless the action is on a stupendous scale. Such changes occur from time to time in the outbursts known as novae or temporary stars. They afford the most convincing proof of all of the presence of dark stars in the Galaxy.

Dwarfs.—The discovery in recent years of exceedingly faint red dwarfs affords another convincing argument in favour of the existence of stars which we fail to see. Those which have been discovered owe their detection entirely to the fact that they are amongst the very nearest of our stellar neighbours. Proxima Centauri is in the last stage before extinction, giving less than one ten-thousandth part of the light of our Sun. It appears to be physically connected with α Centauri, the great pair of suns that form the brighter of the pointers to the Southern Cross. It is about 10,000 astronomical units away from the pair, and must take about a million years to revolve round them. As it is now on the side of its orbit nearest to our system, it is the nearest known star.

Barnard's star, another at the same stage of evolution, though a faint red star of magnitude $9^{m}\cdot7$, is the next nearest known celestial body after the α Centauri group. Other very faint red stars are the companions to Groombridge 34, Pi $2^{h}123$, and Capella.

Since the stars which are nearest to us turn out, as in the case of α Centauri, to have companions that are only visible on account of their proximity, or, as in the case of Barnard's star, to be only visible themselves for the same reason, we may infer that there are innumerable dark stars amongst the luminous members of the Galaxy. Eddington says: "Thus we find the four red dwarfs above mentioned within a very small

distance of the Sun, and doubtless they are equally plentiful throughout the system."

We thus see that recent astronomical observation points to a much greater abundance of dark matter in space than had hitherto been recognized.

Theoretical considerations support the same belief. Since stars have only a finite quantity of energy and are continually losing it by radiation, they can have only a limited period of luminous life. If time is infinite and the universe immortal, it must have reached what will appear to us as approximately a steady state. Systems, therefore, as well as stars must have their life-periods, and to ensure continuity there must be some method of revivification for each. Further, to maintain the steady state, about the same number of giants must be born during any period as there are dwarfs which fade into invisibility. The number of non-luminous stars must therefore bear to the number of luminous ones the same ratio as the average period of non-luminous existence bears to the period of luminous life. This latter ratio is generally believed to be a very large number, and, if so, the non-luminous stars must outnumber the luminous ones very many times. We shall give reasons later for taking the ratio to be about of the order 1,000 to 1. If this idea is accepted it must revolutionize many theories of stellar evolution.

The one objection to the encounter theory which is usually regarded as fatal is the extreme improbability of collisions amongst the stars. T. J. J. See states: "It seems certain that such chance impacts seldom or never take place; owing to the immense mutual distances of the stars, and the small size of their globes, they represent events too purely hypothetical to be of any interest."

Eddington, in *Stellar Movements*, says: "The stars have often been compared to the molecules of a gas, and it has been proposed to apply the theory of gases to the stellar system. The essential feature in gas dynamics is the prominent part taken by the collisions of the molecules. Now, it is clear that collisions of the stars, if they occur at all, must be exceedingly rare; and the effect would certainly not be the harmless rebound contemplated by the theory of gases. It is, however, well known that the precise mode of interaction during the encounter is of little importance, and all that is required in the theory is an interchange of momentum taking place between two individuals in their line of centres."

After referring to the equipartition of energy, he adds: "But it is unnecessary to pursue these deductions, for they have no reference to anything in the present state of the universe or to any future near enough to interest us."

Jeans, in *Problems of Cosmogony and Stellar Dynamics*, calculates the probable mean interval between the collisions of a single star to be 4×10^{12} years—"a period which is so large compared with any reasonable estimate of the age of the universe that it is at once clear that the chance of material collisions may be disregarded entirely."

In all such calculations a number of important factors have been disregarded, and when these are taken into account the case is completely altered. Perhaps the most important of these factors is the one we are considering—viz., the abundance of non-luminous matter. Let us therefore reconsider the estimate made by Jeans.

He takes the mass of the Galaxy as that of 1,500 million stars of average mass 1·7 times that of the Sun (2×10^{33} grams), or a total mass of

5×10^{42} grams. He considers the Galaxy to be a lens-shaped figure of equatorial radius 2,000 parsecs and transverse radius 600 parsecs, the volume being 10^{65} cubic centimetres. The stellar density—that is, the number of stars per unit volume (denoted by ν)—is therefore $10^{-56\cdot5}$. He takes the average velocity of the stars, V, to be 40 km. per second, and assigns to an average star a diameter, σ, equal to that of Neptune's orbit, $4\cdot5 \times 10^{14}$ cm. With these data, using the formula $1/\pi\nu\sigma^2V$ for the mean interval of time between successive collisions, he calculates that this interval is 4×10^{12} years. Taking the number of stars to be 15×10^8, and remembering that two stars take part in one encounter, this would lead us to expect one nova in 5,300 years.

Now, it is evident that the accuracy of this estimate depends on the correctness of the values assigned to ν, σ, and V. Jeans states that "these estimates evaluate the density of the matter *in the bright stars only*; the dark stars, of which it is impossible even to guess at the number, will increase the density to a quite unknown extent, so that the estimates only provide lower limits to the true density."

But is it impossible to guess the number of dark stars? Let us take Jeans's own figures. If the average interval between the successive encounters of a single star is 4×10^{12} years, and if we consider the period of its luminous life to be 4×10^9, then, since the number of dark stars to the number of bright ones is as the duration of the dark period to that of the bright, it follows that the dark stars are a thousand times as numerous as the bright ones. The value of ν in the formula should be multiplied by 10^3, and this variation alters entirely the estimated number of novae, for it increases the probable number of encounters a million times. Thus we should expect 200 novae a year, instead of one in 5,000 years.

It is true that in making his estimate Jeans took the diameter of a star as $4\cdot5 \times 10^{14}$ cm., which is the diameter of the orbit of Neptune. This seems at first extravagantly large, and, if it is so, the insertion in the formula of a more likely value may make the expectation of collision once again almost infinitesimal.

But there is hardly any doubt that stars have planetary systems, and if two stars approach one another so closely that their planets are intermingled it seems unlikely that they will pass without producing perturbations that will lead to an encounter between some pair of the bodies involved. It is quite possible that the orbit of Neptune is not the outermost boundary of the solar system. Undiscovered planets may still exist beyond. See thinks that the radius of the system may be as much as 100 astronomical units.

In making his estimate of the number of collisions Jeans did not take account of gravitation or of any of the other factors which undoubtedly increase the probability of impact. Some of the most important of these are given in the following list:—

Factors increasing the Probability *of the Impact of Stars.*—(1) The presence of dark stars, dark nebulae, &c.; (2) the effect of gravitation; (3) the arrangement of stars in binary and multiple systems; (4) the stars having planets round them; (5) the distribution being by no means uniform, collisions occur most frequently where crowding is greatest; (6) so many stars being giants; (7) some stars having vast nebulous atmospheres.

The theory that non-luminous stars are very much more numerous than luminous ones, whilst clearing away many difficulties, introduces a

fresh one which at first sight appears serious. It is this: If we accept Jeans's estimate of the extent of the Galaxy, but multiply his estimate of its mass a thousandfold, we find that the average stellar velocity should be much higher than is consistent with the results of observation. The change suggested would increase the stellar velocities over thirty-one times. Now, taking the values of the constants adopted by Jeans, the critical velocity of escape from the outskirts of the Galaxy appears to be about sixty-four miles per second. This makes the velocity for a circular orbit about its outskirts over forty-five miles per second. If the Galaxy were of uniform density this would suggest stellar velocities ranging from very small values near its periphery to an average of forty-five miles per second near its centre. These velocities are not inconsistent with the results of observation, whilst velocities thirty times as great certainly appear to be so.

It seems probable, however, that some alterations should be made in the values assigned by Jeans to some of the other constants. Let us take these in order.

First, the average mass of the stars. The estimate of stellar mass is based on Eddington's list of seven well-determined masses. The stars named in this list are all binaries (or multiple systems), and the masses given are those of the combined systems. They are treated by Jeans as if they were single stars, which is quite reasonable if binaries arise by fission. If, however, these systems result from encounter, each represents at least two stars. So for this reason alone, according to the encounter theory, the value of the average mass should be divided by two.

But these systems are not by any means a fair sample of the stars. The average intrinsic luminosity of the seven systems is 9·72 times that of the Sun; so the separate stars are, on an average, nearly five times as brilliant as the Sun. They have therefore exceptionally high intrinsic luminosity. And since high luminosity is associated with great mass, these systems must be far more massive than the ordinary star.

Radial-velocity determinations extend only to the fifth magnitude, and therefore include only those stars which are amongst the nearest, or those which are of unusually high luminosity and therefore presumably unusually massive.

Eddington* estimates the maximum temperature attained by stars of different mass. He states that a mass one-seventh that of the Sun should just attain an effective temperature of 3,000° C. (type M); that a mass half that of the Sun should attain 6,000° C. (type G); that a mass equal to the Sun should attain 9,000° C. (type A–F); whilst a mass two and a half times that of the Sun should attain a temperature of 14,000° C. (type B_5). It therefore appears that all stars less than one-seventh of the mass of the Sun, while condensing from the gaseous state, fail to attain a temperature sufficient to render them luminous. Such stars, therefore, are entirely omitted from statistical calculations based on observations of the luminous stars. Those of rather higher mass (say, one-half that of the Sun) never rise to a temperature high enough to place them in type A or B. Owing to low temperature and small surface they are of low intrinsic luminosity, and therefore invisible unless specially near to us. Most of these also are generally overlooked.

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* *Encyclopaedia Britannica*, vol. 30 (1922), p. 303.

Taking account of these neglected types leads at once not only to a higher estimate of the number of dark stars, but to a further important reduction in our estimates of the average stellar mass. The latter quantity does not appear in the formula by which the number of collisions is estimated, except in so far as it affects the value of V. The value of V adopted by Jeans is deduced from the results of observation, and is probably too low, since stars of small mass are omitted, and it is well known that these move much faster than the more massive ones. Most stars of small mass being invisible to us, and those which are near enough to be seen being so faint as to make radial-velocity determinations difficult or impossible, it follows that in all spectroscopic determinations of velocity the more massive stars receive preferential treatment.

The critical velocity of escape from the surface of a star of mass M and radius R is

$$\sqrt{\frac{2GM}{R}}$$

where G is the constant of gravitation. In the case of gaseous stars in the same state of stability we may consider that the molecular velocities at corresponding points are the same fraction of their respective critical velocities of escape.

Now, in stars of identical chemical composition the absolute temperature is proportional to the mean square of the molecular velocity. Thus if T be the absolute temperature and ρ the density, $T \propto \frac{M}{R}$, but $M \propto \rho R^3$, $\therefore T \propto \rho R^2$, or $T \propto \rho^{\frac{1}{3}} M^{\frac{2}{3}}$.

It follows, therefore, that in similarly constituted gaseous stars at the same temperature the radii are proportional to the respective masses. The surfaces are therefore directly proportional, and the densities inversely proportional, to the squares of the masses. And in similar gaseous stars of the same density the temperature varies as the square of the radius, or as the cube root of the square of the mass. Also, in stars of the same mass the temperature varies as the cube root of the density—that is, inversely as the radius.

These relations have an important bearing on the questions we are considering. If, for example, the mass of a single star were divided into ten equal portions at the same temperature each would have a radius one-tenth of the original. The surface of the original star would be 100 times that of one of the portions, and therefore ten times that of all. The resultant light would thus be reduced to one-tenth of what it was before.

In stars of the same density and at the same temperature the radiation is proportional to the surface—that is, to the square of the diameter. The quantity of heat available is proportional to the mass—that is, to the cube of the diameter. The time taken to cool through a definite range of temperature is thus proportional to the diameter or to the cube root of its mass: that is, the more massive the star, the longer is the period of its luminous life. One star that is ten times the mass of another will take about $\sqrt[3]{10}$ times (that is, a little over twice) as long to cool.

Massive stars therefore figure unduly prominently in statistics based solely on the luminous portion of the universe. Not only are they visible from greater distances, but they remain visible for longer periods, than less massive ones. It is probable also that their non-luminous period is shorter, on the average, as they offer larger targets for collision. A star

that has, for instance, twice the mass of another will have, as we have seen, about twice the diameter, and therefore four times the surface and four times the expectation of encounter. Its period of darkness should therefore be only one-quarter as long. For this reason also stars of great mass must be much less common amongst the dark than amongst the luminous ones. The average mass of all stars is therefore very much less than that of the group whose masses have been determined. Instead of an average 1·7 times the Sun's mass, it seems likely that a value 200 times less would be a better approximation.

With 1,000 times as many stars of average mass $\frac{1}{200}$ of Jeans's estimate, the total mass of the Galaxy would be five times as great. It seems probable also that the value, 2,000 parsecs, adopted by Jeans for the radius of the Galaxy is too small. If it were five times as great the critical velocity of escape would be the same as with the constants used by Jeans. If the density were uniform throughout the system its value would be reduced 125 times, thus reducing the number of encounters. But the effective density is a very different thing from the density found by dividing the total mass by the total volume. Collisions occur where stars are crowded, and the most cursory glance at the heavens shows that stellar distribution is very far from uniform.

CONCLUSIONS.

1. That non-luminous matter is much more abundant throughout the universe than it is generally supposed to be.

2. That this material exists in many different forms.

3. That dark stars are much more numerous in the Galaxy than luminous ones.

4. That the estimates of the average mass of the stars is too high.

5. That, even among the luminous stars alone, Jeans's estimate of 1·7 times the Sun's mass for that of an average star is too high.

6. That, owing to the longer luminous life of massive stars, an undue proportion of these appear amongst the luminous ones. Dark stars are therefore, on an average, less massive than luminous ones, and when they are included they reduce the average mass still further.

7. That this estimate must be still further reduced, because stars of very small mass never become luminous, according to Eddington's calculations.

8. That the average velocity of the stars has been underestimated. It was derived from the brighter and therefore more massive stars, and it is now known that the small stars are moving much faster.

9. That a recognition of the abundance of non-luminous matter in space removes the only serious objection that has been raised to the encounter theory of rejuvenation of stars, and thus prepares the way for a rational and satisfying cosmology.

In nearly every theory that has been framed hitherto to account for the present constitution of the universe an attempt has been made to trace the development of all cosmical forms from chaotic matter in the state of wide nebulous diffusion. The whole mass from which any body or system arose is generally assumed to have been endowed initially with rotation sufficient to account for existing moments of momentum. These assumptions appear arbitrary and unjustified. They arise from the belief that the universe is of limited age, and that it is rushing through various stages from youth to maturity, or from maturity to senescence and decay.

But have we any right to suppose that the present epoch is in anyway a special and peculiar one in the history of the universe? Early theories of cosmogony were vitiated by the assumption that the Earth was the fixed centre of all things, and that everything else existed simply to minister to the Earth. Recent theories are vitiated in a similar way by the assumption that the present moment is of unique and special importance in the ages of infinite time.

Imagine a being whose life-period is a single second, but whose senses are so alert that the one second appears to him as a hundred years to us. Let him study the evolution of some species of plant or animal life. By observing living forms of various ages he will be able to trace the life-history of an individual. But could he hope to trace the course of evolution from protoplasm to an oak-tree? So we, in our brief span, may reasonably hope, by studying stars in all stages, to learn the life-history of a star. By studying systems in different stages of development we may even hope to trace the life-history of a system. But it would be as impossible to show that a spiral nebula develops into a solar system as that an elephant develops into a colony of ants.

If the contention is sound that the present moment is not of greater importance than any other in the duration of infinite time, then it follows that though the Sun may cool, though individual stars may fade into darkness, the Galaxy persists: though even the Galaxy and other great cosmic systems sink into invisibility, yet a hundred million, a thousand million, or a million million years hence the universe as a whole will be much the same as it is now. A cloud on a mountain-top, or the traffic on London Bridge, seen from a distance, may appear unchanged, though every drop of water in the one, and every individual in the other, may be entirely different. The fact that every luminous star is losing heat and passing gradually into darkness is no evidence that the universe is dying. If this is so, we should not seek to trace the origin of the Galaxy from a vast diffused nebula, but should expect to find that stars give birth to stars, systems to systems.

This outlook simplifies greatly the problems of cosmology, and removes otherwise insuperable difficulties. If all stars started together to condense from the primal galactic nebula, how is it that any stars are visible now? Even if the nebular stage is assumed to be sufficiently recent, how was the nebula formed, and why are stars now found in every stage of development? If all started together, the small ones should all be far advanced and the large ones at earlier stages, which is not the case. There must, then, be some mode of revivification of stars, and every star that is now luminous must have been reborn at an epoch not too far in the past.

The labours of the Harvard astronomers and the researches of Professor Henry Norris Russell and others have given us a fairly clear and complete picture of the life-history of a star from the time that it appears as a giant M until it finally returns to the M type as a dwarf. But two questions remain unanswered: What happens to the dwarf M stars after they have cooled so as to be no longer visible to us? And where do the giants come from, and how is the continuous supply kept up? For endless ages dwarf M stars have been fading into darkness. Untold millions must exist in space. Is it not reasonable to suppose that dead dwarfs are able to undergo some process of revivification and arise as giants in all their strength? What more likely mode of transformation is there than the encounter of dead stars?

HISTORY OF ROSS DEPENDENCY.*

By H. T. FERRAR, M.A., F.G.S.

THE history of the Ross Dependency, the territory lately added to the Dominion of New Zealand, is similar to that of New Zealand, for both were discovered by expeditions sent out by the British Government to explore the Antarctic regions, and both were annexed to the British Empire about the same time.

Captain James Cook, who was aware that Tasman had discovered land to the eastward of Australia, virtually discovered New Zealand for us, and, proceeding southwards to explore the supposed Antarctic continent after proving that New Zealand was not part of the same, he saw snowy undulating country in latitude 71° south, longitude 111° west, which undoubtedly adjoins the present Ross Dependency on the west. In the early part of the nineteenth century British and other whaling-ships cruised in New Zealand waters, but no discoveries pertinent to the present subject were made until 1839, when John Balleny, in one of Messrs. Enderby's whaling-ships, discovered what are now called the Balleny Islands.

During the years 1839 to 1842 the British Government maintained an expedition at sea, one of whose duties was to make magnetic observations in high southern latitudes. This expedition, under the command of Captain (afterwards Sir) James Clarke Ross, sailed in the two ships, the "Erebus" and the "Terror," which later were lost in the Arctic regions when Franklin perished. Ross sailed from Tasmania, passed through the Antarctic pack ice, discovered mountainous country, landed on an island (Possession Island), and took possession of the surrounding country on the 12th January, 1841.

Ross, who aspired to attain the position of the South Magnetic Pole as he had already attained the North Magnetic Pole, was turned southwards by the trend of the land which he named Victoria Land. Eventually he sighted a steaming volcano, 13,350 ft. high, which he named Mount Erebus; the adjacent smaller quiescent volcano was called Mount Terror. Still endeavouring to get round the south end of the newly discovered land, the South Magnetic Pole being to the westward of the coast, he was again turned aside by a perpendicular wall of ice, which he called the Great Ice Barrier because it formed a barrier to his ships proceeding farther southwards. After cruising along this ice-wall until involved in dangerous floating ice, he returned north to New Zealand to refit his expedition.

From this time no ships visited South Victoria Land until 1895, when a Norwegian whaler, with C. E. Borchgrevinck before the mast, sought whales in what is now the Ross Sea. Borchgrevinck followed up this experience by inducing Sir George Newnes to fit out an Antarctic expedition (the "Southern Cross," 1899) which, among other things, proved that it was possible for human beings to exist on South Victoria Land throughout an Antarctic winter.

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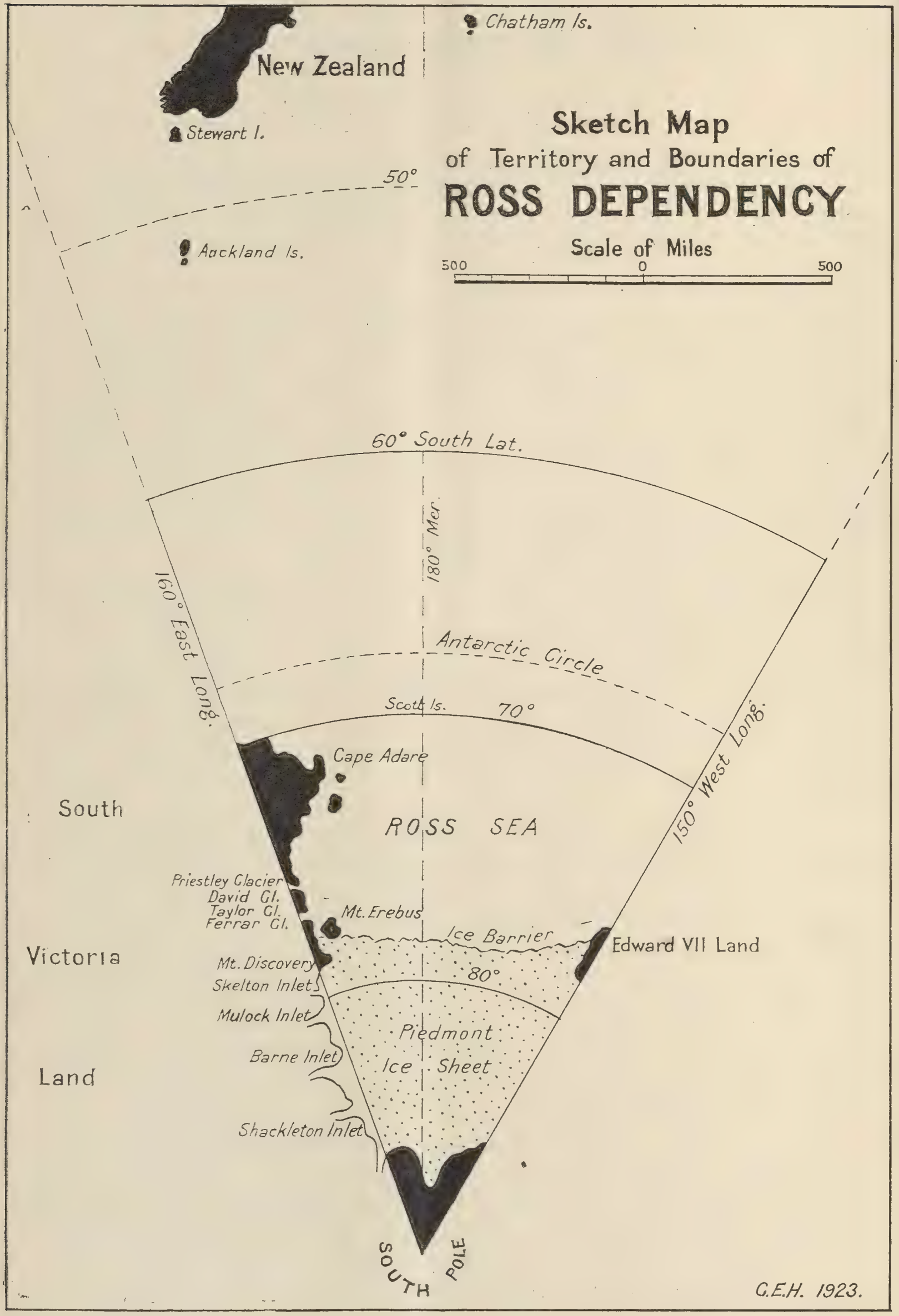
* Paper read at a meeting of the Historical Section of the Wellington Philosophical Society on the 14th August, 1923.


New Zealand
Chatham Is.
Stewart I.
Sketch Map
of Territory and Boundaries of
ROSS DEPENDENCY
Scale of Miles
500 0 500
50°
Auckland Is.
60° South Lat.
180° Mer.
160° East Long.
Antarctic Circle
Scott Is.
70°
Cape Adare
South
ROSS SEA
150° West Long.
Priestley Glacier
David Gl.
Taylor Gl.
Ferrar Gl.
Mt. Erebus
Ice Barrier
Edward VII Land
Victoria
Mt. Discovery
80°
Skelton Inlet
Mulock Inlet
Piedmont
Barne Inlet
Ice Sheet
Land
Shackleton Inlet
SOUTH POLE
G.E.H. 1923.

International rivalry and the need for further Antarctic research were reasons which led the Royal Geographical Society to approach the British Government for financial help towards equipping an expedition to the south polar regions. A ship, the "Discovery," was specially built for the purpose, and Captain R. F. Scott was placed in command. The "Discovery" sailed from England in August, 1901, reached New Zealand in December of the same year, and entered the pack ice of Ross Dependency on the 3rd January, 1902. Landings were made at Cape Adare, where Borchgrevinck wintered; at Coulman Island, where a letter of arrival was deposited; at Cape Crozier, on Mount Terror; and in the Bay of Whales, where Amundsen had his winter quarters. From this point the "Discovery," after sighting Edward VII Land, returned to the west side of Mount Erebus, and went into winter quarters in McMurdo Sound. Here the ship was frozen into the ice for nearly two years, and during that time long sledge journeys were made in many directions. Details of these journeys may be found in Scott's narrative of the expedition, *The Voyage of the "Discovery,"* published in 1905.

The next expedition to our new dependency was made by Shackleton in the "Nimrod" (1908–10). Shackleton had been an officer under Scott on the "Discovery," so knew the country, and was thus easily able to beat Scott's (and his own and Wilson's) "farthest south" latitude. He and a party attained to within 100 geographical miles of the South Pole, another party reached the South Magnetic Pole, and a third party climbed to the top of Mount Erebus.

Scott's second expedition, this time on board the "Terra Nova" (1911–13), is well known owing to the heroic action of Oates dropping out to save his companions, and owing to the disaster which overtook Scott, Wilson, and Bowers when they were so near a depot of food. Scott and his party reached the South Pole a month after Amundsen, who had given out to the world that he was making a voyage to the Arctic regions.

In 1914 Shackleton set out on his third expedition to the South Pole, but his ship was lost on the South American side of the world, and that portion of his expedition which entered the Ross Sea area added little to our knowledge of this region.

Finally, about the 4th August, 1923, the Ross Sea area was handed over to the jurisdiction of New Zealand under the name of "Ross Dependency." The dependency is defined as all the territory and seas to the south of latitude 60° south, which lies between the longitudes 160° east and 150° west. The sector of the south polar regions thus allocated to us includes Edward VII Land, discovered by Scott; the great icy barrier now known as the Ross Piedmont; the Ross Sea; and the front only of South Victoria Land. Most of the mountain-ranges of South Victoria Land lie to the west of longitude 160° east, and are therefore outside the Ross Dependency, as is also the hinterland plateau which lies behind them. The general outline of Ross Dependency has been fairly accurately charted, but there are two comparatively large areas which remain unexplored—namely, the Admiralty Range, with its hinterland as far as Oates Land, and Edward VII Land with its hinterland.

Descriptions of the new dependency are to be found in the narratives of the leaders, and in the narratives written by other members of the various expeditions. The scientific reports concerning the Ross Dependency have

been and still are being published by the official bodies or publishing firms shown in the following :—

(1.) *Southern Cross Collections.* British Museum (Natural History). 8vo. 1902.

(2.) *National Antarctic Expedition, 1901–4 ("Discovery") :—*
(*a.*) Natural History. Brit. Mus. (Nat. Hist.). 4to. 1907–8.
(*b.*) Physical, Meteorological, &c. The Royal Society. 4to. 1908–9.

(3.) *British Antarctic Expedition, 1907–9 ("Nimrod").* W. Heinemann, London. 4to. 1914.

(4.) *British Antarctic ("Terra Nova") Expedition, 1910 :—*
(*a.*) Natural History. Brit. Mus. (Nat. Hist.). 4to. 1914.
(*b.*) Physiographical (Scott Fund). Harrison's and Sons, London. 4to. 1922.

The reports of Sir Douglas Mawson's "Aurora" expedition, which deal with the territory immediately to the west of Ross Dependency, make frequent reference to our area. These reports are being published by the Government Printer, Sydney, and have been appearing at intervals since 1916.

More or less complete sets of these publications may be found in various libraries throughout the Dominion, and in the libraries of two or three New-Zealanders who have been members of one or other of the above-mentioned expeditions.

The Ross Dependency has been handed over to the New Zealand Government free of cost, its exploration and the publication of the scientific reports having been paid for mainly by the British Government. The explorers of the new dependency are indebted to the people of New Zealand for much financial help and hospitality.

MOULDS ON FROZEN MEATS.

By A. M. WRIGHT, A.I.C., F.C.S., Chief Chemist, New Zealand Refrigerating Company, Limited (formerly Bacteriologist, N.Z.E.F.).

THE results which are now published have been recorded during an investigation covering mould-development on frozen meats. This investigation was commenced in England during 1917, and continued in New Zealand from 1919 to the present time.

In 1917 specimens of tissue covered with black spots were submitted for examination to the author, who at that time was in charge of an Army bacteriological laboratory in England; the specimens had been taken from mutton received in a frozen condition.

Examination showed that a growth of mould had taken place upon the surfaces of the tissues; microscopically, the distorted structure of the mould appeared to be a *Mucor*, but all attempts at culture on Sabouraud's and potato media at room-temperature 20° C. and 37° C. failed, for the reason, apparently, that, after the initial growth on the surfaces of the

meat had commenced, the spores, which possibly had not developed fully, were destroyed by the low temperature at which the meat was held during the subsequent cold storage.

Cultures upon nutrient agar and in bouillon at 37° C. and at room-temperature showed a gram-negative coccobacillus; these when cultivated at room-temperature developed colonies of a deep-red colour on nutrient agar; the colonies on standing for several weeks became dark in colour; it was concluded that the micro-organism was *B. prodigiosus*, or possibly a strain of this organism—namely, *B. indicus*.

It is of interest to note that Klein (1), in his work on black-spot, found a harmless aerococcus which appeared to be symbiotic with the moulds found by him on refrigerated meat. It seems probable that the coccobacillus found in the case under review bears a similar relationship to the *Mucor* associated with the black-spot.

In 1919, upon returning to New Zealand, the author was called upon to investigate further instances of mould-development on frozen meat, especially in regard to black-spot. The first of these investigations showed that the growths of mould on the frozen meat examined in the cold stores were *Mucor mucedo* and a *Rhizopus*. These moulds were cut from the surfaces of the black spots and identified microscopically and culturally, the identity of the fungi being confirmed upon the mea and in culture by Dr. A. B. Pearson, bacteriologist to the Christch r Hospital.

During the course of the investigation of other occurrences of mould-development on frozen meats in cold stores, the associated mould upon the black spots, in addition to the *Mucor* and the *Rhizopus*, was *Penicillum glaucum*. In only one case was *Cladesporium herbarum* definitely identified as the mould associated with the black-spot, and in this case, upon the same carcases and on others, were found black spots upon which the associated fungi were either a *Mucor* or a *Rhizopus*.

Brooks and Kidd (2), in their report upon the black-spot of chilled and frozen meat, attribute the discoloration to *Cladesporium herbarum*, which they find can grow and produce black spots on meat kept at a temperature of —5·5° C. (*i.e.*, several degrees below freezing-point).

The results recorded by Brooks and Kidd are confirmatory of the earlier work carried out by Massee (3), in which he states that *Cladesporium herbarum* grew appreciably at 0° C., and that the growth below this temperature was very slow.

Klein (1), reporting upon brown spots on chilled beef, found that the fungus causing the infection (a Saccharomyces) grew at a temperature as low as —2° C., but that at —9° C. there was no growth.

Monvoisin (4, 5) states that the moulds usually found on frozen meats are *Thamnidium elegans*, *Mucor mucedo*, a *Rhizopus*, and *Penicillum glaucum*.

The author during the course of this investigation has found that when *Mucor mucedo* has been grown on meat at temperatures ranging from —2° to —1° C. until the growth is well established, and then placed in cold storage at a temperature of —12° to —15° C., a black spot has developed. Similar results have been obtained with *Penicillum glaucum*, except that the temperature of initial development was about 4° C.

These results, together with those found when investigating the actual conditions under which mould and black-spot occur in cold storage, indicate that no one species of fungus is responsible for the condition known as

black-spot on frozen meat, and that *Cladesporium herbarum* is but one of a number of moulds which are capable of producing the discoloration noted, and, as far as New Zealand is concerned, it would appear that of that number *Cladesporium herbarum* is the least common of the causal agents.

In every instance where it has been possible to investigate the conditions in the stores in which mould and black-spot has developed on frozen meat the author has been able to demonstrate from the ample evidence available that the temperature in the cold stores had reached at least 0° C. after the meat had been stacked therein, and the indications showed that these temperatures had either been reached upon several occasions or that the temperatures had been maintained thus for some time.

In several cases it was found that actual putrefaction of some carcases in the store had taken place; while in several instances the presence of sheet-ice formations and icicles formed by the melting of the snow crystals upon the roof and pipes which, dripping water upon the carcases, re-formed as ice or as icicles afforded evidence that after storage the temperature had been high enough to melt the snow crystals—certainly above 0° C.—thus affording an opportunity for the development of any mould-spores which are commonly, perhaps always, present in the air; in some cases the temperature had been high enough, and held thus for a sufficient time, to enable putrefactive bacteria to develop and produce actual decomposition of the meat.

It has also been demonstrated, in every case of mould-development which has been investigated at the point of origin by the author, that either defective insulation has been responsible for the rise in temperature, or that the methods of storage have been such that warm air has been admitted from time to time when placing the recently slaughtered stock in the stores, and the air thus admitted has been in such quantities as to cause a temperature-rise above 0° C. in certain portions of the store.

It has been pointed out that, in general, mould and black-spot have been associated with meat held for a prolonged period in cold storage, and it has been stated that prolonged cold storage was the responsible factor in producing the condition. The author has found mould upon meat held in cold storage for as short a period as one month; and, on the other hand, has found meat held under strict supervision as to temperatures and sound insulation to be free from mould after nine years' cold storage.

The actual explanation of the fact that mould and black-spot were found on meat which had been subject to prolonged cold storage does not lie in the prolonged storage itself, but with the conditions associated with that prolonged storage; these conditions being the congested state, with the consequent inaccessibility of the store for frequent supervision to determine that no local fault in the insulation had developed, with its attendant imperfection as regards refrigeration.

Despite the fact that it has been found that a mould which has been identified as one of the causal agents of black-spot can be artificially grown at —5·5° C., this should not be a serious factor in regard to frozen meats, for it will scarcely be maintained that —5·5° C. is either a usual or safe temperature at which frozen meats should be held.

It has happened that certain apparent growths upon frozen meats have been regarded as mould, and the author has on two occasions found that such mistaken conceptions have temporarily caused delay in ship-

ment. It had been reported that a feathery growth of mould was found upon the interior of the neck and upon the cut surfaces up to the breast of certain carcases; this feathery growth was not found upon the other surfaces of the meat.

Similar feathery growths can be found on most frozen mutton and lamb, but only upon the cut surfaces about the neck and breast, or other surfaces cut during the dressing of the carcases, and seldom or never upon surfaces cut after rigor mortis. These feathery growths upon frozen meats, while resembling moulds to some extent, are really deposits of feathery crystals of salts and organic compounds which separate from the meat-juices during freezing. Microscopic examination clearly shows the nature of the apparent mould; the application of a drop of water will at once dissolve the crystals; yet in the instance noted an apparently competent medical authority (now deceased) reported the growth as mould.

It was also reported that a certain new mould had been discovered on some carcases of frozen lambs. The authority reported that it showed well-defined mycelium, but no sporangia, and that it could not be grown in artificial culture media. It was subsequently demonstrated that the material in question was the cotton-fibre from the bagging, which had adhered in part as fluff to the blood-stained surfaces of the neck from which the specimen was removed for examination.

These instances are noted in order to emphasize the necessity for securing competent advice in all cases of reported mould-development on frozen meat, especially when the circumstances might lead to the rejection of the meat.

From the results of the investigations conducted under conditions which have enabled the author to study the development of moulds on frozen meat at the point of origin the following conclusions have been reached (6) :—

(1.) That " black-spot " is not the result of the growth of any particular mould.

(2.) That many moulds which have been permitted to grow on meat will produce a dark spot, varying from brown to black, if frozen after growth has become well established.

(3.) That prolonged cold storage is not of itself a predisposing factor in mould-development.

(4.) That mould-development on frozen meats is not brought about by any condition unusual to normal mould-development.

(5.) That in order to prevent mould-development in cold stores it is necessary that the meat be held at temperatures substantially below that at which mould can grow; this temperature should not be higher than —9° C.

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SOME NEW ZEALAND GLASS-SANDS.

By F. T. SEELYE, Dominion Laboratory.

AN inspection of the annual reports of the Dominion Laboratory would seem to show that quartz sands are fairly abundant throughout the Dominion. Samples have been received from many districts, extending as far north as Hokianga, and south as far as Puysegur Point. As there was probably little prospect of the immediate use of these for glass-making in the earlier days, complete analyses were seldom made, but the possibility of glass being manufactured on a large scale in New Zealand in the near future has revived interest in the nature and extent of our quartz sands, and several samples of a fair degree of purity have lately been received.

According to the reports, samples of siliceous sand have been received from the following localities: Puysegur Point, Tingira Sound, Kowhai Pass, Rakaia Gorge, Picton, Papakura, Frasertown (Wairoa), and Manukau Heads. Sands specially mentioned by the Analyst for their suitability for glass-making purposes were received from the following places (Analyst's remarks are also given): Manukau Heads—"Sand suitable for glass-making." Malvern Hills—"An almost pure quartz sand." Motupipi—"A very fine siliceous sand consisting principally of quartz; might be suitable for glass-making." Waingorai Bay—"A remarkably pure quartz sand, well adapted for the manufacture of certain kinds of glass."

In the case of the following samples analyses are also given:—

	(1.)	(2.)	(3.)	(4.)	(5.)
Silica (SiO_2) ..	95·95	95·42	96·54	96·04	97·73
Alumina (Al_2O_3) ..	1·88	2·01	0·72	2·44	1·32
Ferric oxide (Fe_2O_3)		0·40	0·32	0·16	0·30
Lime (CaO) ..	1·16	None*	0·16	0·15	0·02
Magnesia (MgO) ..	0·11	None	0·24	0·07	0·02
Loss on ignition ..	0·25	1·72	1·68	0·85	0·37
Alkalis, &c. ..	0·65	0·45	0·34	0·29	0·24
	100·00	100·00	100·00	100·00	100·00

No. 1: White quartz sand from Rawene (Hokianga).

No. 2: A supposed clay from Hukerenui, but really an exceedingly fine-grained sand containing a few coarse particles.

No. 3: A highly siliceous clay from Onetea.

No. 2 would probably, and No. 3 almost certainly, contain too much of the "silt" or "mud" grade of particles to be used for glass-making.

Nos. 4 and 5 are highly siliceous sandstones from Bombay, in the Waikato, but the degree of coherence of the rocks is not stated.

It may be of interest to examine these analyses in detail:—

Silica content: This is not as high as desirable. Boswell, in his *British Resources of Sands and Rocks used in Glass-making*, states that 98 per cent. of silica is desirable for most glass-sands, while for the best work 99·5 per cent. or more is preferable. As examples may be mentioned

Nievelstein sand, 99·95 per cent.; Lippe, 99·8 per cent.; Fontainebleau, 99·7 per cent.; Berkeley Springs, U.S.A., 99·65 per cent.; Dutch, 99·63 per cent.

Alumina, lime, and magnesia: These are refractory bases, and their presence tends to lengthen the time of melting in making glass. Sands almost free from them are generally preferable, especially as those containing these bases are usually high in ferric oxide also. The alumina is generally present in the form of feldspar or its decomposition product, kaolin. Its presence in some cases may actually be an advantage, as for bottle-making, where strength and toughness are required. It seems not unlikely, too, that alumina prevents the devitrification of glass.

Ferric-oxide content: This is not given for the Rawene sand, but is much higher in the other cases than is desirable for the best glass-work. Iron oxide is the impurity least desired, as it imparts a yellow or green colour to the glass, although this may be corrected, to some extent, by the addition of decolorizers, such as manganese dioxide, arsenious oxide, nickel oxide, selenium, &c. For dark-green bottle glass the ferric oxide may reach as high as 2 or 3 per cent., or even more; for sheet glass for windows, from 0·15 to 0·25 per cent., or even more. For plate glass, chemical apparatus, glass chimneys, globes, &c., sands containing up to 0·1 per cent. may be used, but for the best tableware not more than 0·05 per cent. is desirable, while for optical glasses not more than 0·03 per cent. should be present.

Iron-bearing minerals, such as magnetite, ilmanite, and complex iron silicates, are usually present in the small crop of heavy minerals which can be separated from practically every glass-sand; but, as the percentage amount of the whole crop of these minerals is usually extremely small, it is not the iron so present that is harmful, but rather that present as a coating of limonite or haematite on the quartz or feldspar grains themselves, and occasionally present within the grains, and also that associated with the clay material of the sand. Hence the desirability of examining the sand microscopically to determine whether such coatings are present or not. In this connection it may be noted that the washing of the sand, although adding to the cost of the material, not only serves to remove much objectionable clayey matter and very finely divided quartz, but also often very greatly reduces the amount of iron oxide present.

It is noteworthy that all the most famous glass-sands of Europe—those of Lippe, Hohenbocka, Fontainebleau, &c.—of high silica and low iron-oxide content, occur associated with carbonaceous material, the probable explanation being that by the reducing-action of the organic matter the ferric compounds are reduced to the ferrous state, and then carried off by percolating water. This fact, and the further one that most of the best glass-sands are of late geological age, may prove valuable aids in the search for glass-sands in our own country.

Alkalis: In the above analyses these have been determined by difference, and hence bear the sum of the errors of the analyses. The alkalis exist in the sand chiefly in the form of feldspars.

Titanium and zirconium in sands: The presence of these substances is always very objectionable in glass-sands, on account of the highly refractory nature of their compounds.

CHEMICAL ANALYSIS.

As regards the chemical analysis of sands, the usual method for silicates is followed with special precautions in the determination of silica and iron. The sample, after fusion with sodium carbonate, is dissolved in dilute hydrochloric acid, and the silica separated by three evaporations with intervening filtrations. The purity of the silica is checked by evaporation with hydrofluoric and sulphuric acids. The iron and alumina may be precipitated by ammonia with the usual precautions, and from this precipitate, after fusion with pyrosulphate and evaporation with sulphuric acid, the "extra" silica may be separated, and the iron and titanium then estimated colorimetrically. The lime and magnesia are determined in the filtrate from the iron-alumina separation by the usual methods. The alkalies are estimated by the J. Lawrence Smith method.

Chemicals of the highest degree of purity are essential for the best work, and the small amounts of impurity they contain should be known; if necessary, a blank analysis may be made.

As the amount of iron in a sand is of so great importance it is customary to determine it directly in a separate sample. This is attacked by hydrofluoric and sulphuric acids, after which the former and most of the latter are expelled by evaporation. After diluting and filtering, any residue left should be fused with a little iron-free potassium pyrosulphate, and the melt dissolved in dilute sulphuric acid. Should any residue still remain it may be collected, fused with iron-free soda, and the melt again dissolved in sulphuric acid. The filtrates are combined for the colorimetric determination of the iron. A useful modification of the thiocyanate colorimetric method for the determination of iron, due to Motejka, is described in the *Journ. Chem. Soc.*, vol. 120 (1921), Abs. ii, 658.

MECHANICAL ANALYSIS.

Of equal importance with the chemical composition is the grade of a glass-sand—that is, the size of the particles forming the sand, and the relation between the amounts of the various sizes. Boswell has adopted the following grades in his mechanical analyses of British sands:—

Particles greater than 2 mm. diam.	Gravel.
Sand grades—	
Particles greater than 1 mm. and less than 2 mm. diam. ..	Very coarse sand.
,, 0·5 mm. ,, 1 mm. diam. ..	Coarse sand.
,, 0·25 mm. ,, 0·5 mm. diam. ..	Medium sand.
,, 0·1 mm. ,, 0·25 mm. diam. ..	Fine sand.
Silt grades—	
Particles greater than 0·05 mm. and less than 0·1 mm. diam.	Superfine sand.
,, 0·01 mm. ,, 0·05 mm. diam.	Silt.
Particles less than 0·01 mm. diam.	Clay grade, or mud.

The mechanical analysis is carried out by means of sieves for the coarser material, but for the finer grades some form of elutriator is necessary.

The same author has shown from the mechanical analyses of glass-sands actually in use that a sand should have at least 70 per cent., and if possible 90 per cent., of one grade, and that this grade should be in most cases medium sand. If the fine sand forms the bulk of the deposit, so much the better, but such sands are rare. A distribution of the bulk of the sand between these two grades is not objectionable.

The total amount of all the sand grades (less than 2 mm. and greater than 0·1 mm.) should rarely be less than 95 per cent. for glass-sands. A sand should not contain much of the silt grades, and the clay grade should be absent.

The importance of procuring sand the bulk of which consists of the medium or fine grade is as follows: In melting on a very large scale in "tank" furnaces any extremely fine material is apt to be blown out of the charge by the blast of air and gas, and the composition of the batch thus changed. Further, the fine material may entrap air-bubbles, which are difficult to remove later from the molten mass. The finest particles melt before the coarser ones, the resulting molten material sinks to the bottom, and the composition of the whole is not uniform. If very coarse particles of sand are present these are difficult to melt, and they may even remain as partly undigested lumps in the glass. On the other hand, with a well-graded sand the whole of the batch passes smoothly into the molten condition at almost the same moment. In this connection it may be mentioned that sands consisting of angular and subangular grains are desirable, as they melt more rapidly than those consisting of rounded grains.

Melting of the best classes of glass is usually conducted on a much smaller scale in covered pots. Here there is less danger of the blowing-out of the finer material, and uniformity of composition is more easily obtained. Hence, for high-class glassware the chemical composition of the sand is all-important, and the grade of the sand often takes secondary place.

In the case of the following New Zealand sands both the chemical analysis and the grading test are given in the annual reports of the

Laboratory :—

	(1.)	(2.)	(3.)	(4.)	(5.)	(6.)	(7.)
Silica (SiO_2)	96·71	99·04	98·26	97·85	99·04	98·44	99·20
Alumina (Al_2O_3) ..	0·92	0·48	0·80	0·93	0·21	0·78	0·35
Ferric oxide (Fe_2O_3) ..	0·28	0·07	0·14	0·08	0·08	0·08	0·05
Titanium dioxide (TiO_2)	Undet.	0·03	0·05	Undet.	0·19	0·04	0·02
Lime (CaO)	None	None	0·04	None	None	0·03	Undet.
Magnesia (MgO) ..	0·14	None	0·02	0·18	0·02	0·03	Undet.
Potash (K_2O) ..	None	None	0·12	0·28	0·09	0·09	Undet.
Soda (Na_2O)	None	None	None	0·04	None	None	Undet.
Loss on ignition ..	1·95	0·36	0·51	0·55	0·34	0·49	0·33
	100·00	99·98	99·94	99·91	99·97	99·98	99·95

Grading tests :—

	(1.)	(2.)	(3.)	(4.)	(5.)	(6.)	(7.)
Gravel	0·1	..	..	..	..	..	..
Very coarse sand ..	0·9	0·75	0·16	93·4	..	..	..
Coarse sand		55·20	19·7	4·2	9·3	0·1	0·1
Medium sand ..	2·4	25·35	58·54	1·0	76·5	20·7	23·8
Fine sand	10·9	11·7	14·40	0·8	8·6	73·3	70·8
Superfine sand ..	30·3	7·0	7·2	0·6	3·3	1·9	3·35
Silt	55·4				..	..	..
Clay		..	..	..	2·3	4·0	1·95
	100·00	100·00	100·00	100·00	100·00	100·00	100·00

(1.) White angular sand, two miles south of Kaitara, Purua Survey District.
(2.) Sand from Mount Somers.
(3.) Sand from near Christchurch.
(4.) Sand from Walton Park, Fairfield.
(5.) Sand from Takaka, Nelson District.
(6.) Sample taken by the Inspector of Mines from Mount Burnwell Coal Company's lease, Mount Somers.
(7.) The previous sample after being washed.

MINERAL ANALYSIS.

As a rule, sands contain only a small proportion of heavy minerals—that is, minerals of specific gravity greater than 2·8. These are detrital minerals derived from older rocks. In very pure sands the crop of heavy minerals may be as low as 0·01 per cent., but occasionally it rises to 4 or 5 per cent. Usually it is found that the coarser the sand becomes the smaller is the amount of the heavy crop. If the heavy minerals are present in large quantity they affect the chemical composition of the sand very considerably. Aluminium is usually abundant in the heavy residue, but lime-bearing silicates are small in amount, as most of these tend to decompose and disappear first, followed by the ferro-magnesian minerals, and finally by the aluminous silicates, leaving only certain iron-ores, rutile, tourmaline, and zircon.

In order to separate the crop of heavy minerals from the sand, the sample is dried, and then mixed with a liquid of high specific gravity, the most suitable for this purpose being bromoform (sp. gr. 2·84). This may be done in an ordinary funnel fitted with rubber tubing and spring clip. When separation is as complete as possible the heavy portion of the sand at the base of the funnel is tapped off, filtered from the heavy liquid, and washed. The crop is then examined microscopically, or a partial separation of the different minerals may be made by magnetic or electro-magnetic treatment, or by treatment with still heavier solution.

Mineral analysis is much more rapid than chemical analysis, and yields information as to the chemical compounds present and their relative abundance. A check upon the chemical analysis and a knowledge of what elements to look for are thus obtained.

In conclusion, it may be said that the analyses given above appear to represent all that has been published concerning glass-sands in New Zealand. Among these sands, with the exception of those from Christchurch, Mount Somers, and Takaka, little has been proved suitable for good glass-work, and even these three leave something to be desired for the finest work, either as regards silica or ferric-oxide content, or in the matter of grading. Should further search be made for glass-sands it is very desirable that the samples taken for chemical and mechanical analysis should be thoroughly representative of the whole deposit, and that, if possible, information should be obtained as to the extent, uniformity, and accessibility of the deposit.

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*SPILONOTA MACROPETANA** IN NEW ZEALAND.

By ALFRED PHILPOTT, Cawthron Institute, Nelson.

THIS Australian moth has recently become established in New Zealand. It was first brought under my notice by Mr. B. Chambers, of Havelock North, who, on the 20th March, 1923, sent me a few leaf-rolling

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* *Spilonota macropetana* (Meyr.), *Proc. Linn. Soc., N.S.W.*, vol. 6, p. 683 (1881).

caterpillars which he found feeding on his eucalyptus. Only one of these larvae was reared out, the moth emerging from the pupa on the 11th April. In the following September two larvae were found locally on *Eucalyptus globulus*, and these produced imagines on the 26th September and 6th October. It is therefore evident that the moth is at least double-brooded, there being an autumn and a spring emergence.

S. macropetana is a very obscurely marked species, but is not likely to be confused with any other New Zealand member of the genus except *S. ejectana* (Meyr.). From this it differs chiefly in point of size and the proportionately longer and narrower wings, which have an expanse of from 16 mm. to 20 mm. The colour of the forewings is ashy-grey, more or less suffused with white. Along the costa the dark colour forms a series of short oblique strigulae, and towards the termen there are a number of obscure dark streaks. The most characteristic marking consists of three or four linear black dots above the tornus. The hindwings are fuscous-grey.

Spilonota macropetana; × 2½.

From the fact that the larvae kept under observation pupated on the bottom of the cage in a cocoon of silk covered with debris, it may be concluded that under natural conditions pupation takes place on the ground and not between spun leaves, as is usually the case with leaf-rollers.

In Australia *S. macropetana* is widely spread, being found in Queensland, Victoria, New South Wales, South Australia, and Western Australia. The species does not seem to be regarded as of any economic importance in its native country, but it is not impossible that it may develop into an injurious insect in New Zealand, as it has probably been introduced without its controlling parasites.

I am indebted to Dr. Jefferis Turner for the identification of the species and for information as to its distribution in Australia. Mr. William C. Davies, of the Cawthron Institute, has kindly supplied the accompanying photo.

PROFESSOR E. H. WILSON ON NEW ZEALAND FORESTS AND FORESTRY.

By L. COCKAYNE, Ph.D., F.R.S.

CERTAINLY no one with as wide a knowledge of the woody plants of the earth, both growing wild and cultivated, as Professor E. H. Wilson has ever visited this country. As the result of a rapid survey of the lowland and montane vegetation from northern Auckland to Foveaux Strait he has published a short account of the indigenous forests. He also took advantage, at the same time, of the opportunity of studying the behaviour of the greater part of the introduced exotic trees. For the information of those not conversant with present-day horticulture—using that term in a wide sense—it may be pointed out that Professor Wilson is the Assistant Director of the celebrated Arnold Arboretum of Harvard University; also, he stands second to none of that indomitable band—largely British—whose collective work has brought into horticulture and silviculture that wealth of exotic plants which constitute the garden and woodland floras. Wilson's work was prosecuted for many years in the unbotanized high-mountain area of western China. He also collected assiduously in other parts of that vast country, and likewise in Korea, Formosa, and Japan. Recently he has made a circuit of the globe in quest of further information concerning trees and shrubs, and it was during this extensive scientific tour that he visited this country. Certain impressions of that visit are presented in two papers which have recently appeared in the *Journal of the Arnold Arboretum*.*

Now, as a rule, one is apt to look askance at statements, and especially generalizations, made by those who have paid only a brief visit to a country. But in the case of Professor Wilson it is different: not only has he the peculiarly wide knowledge, as already explained, which enabled him to institute comparisons between our forests and those of temperate lands in general, but, thanks to the guidance of the State Forest Service, he was enabled to see in a few weeks far more of the salient features of the plant covering than, unassisted, he could have done in as many months; also, he came in contact with nearly every one in the Dominion whose opinions on the matters under investigation counted. In short, these papers here being considered are an important contribution to New Zealand forestry, and must be carefully read by all interested in both its purely scientific and practical aspects.

In the first paper, cited above, some of the characteristic features of the rain-forest are vividly described. For example, in the kauri forest, "The trunk [of the kauri] is clean, cylindric with no taper, and from 50 to 75 or more feet long, and is clothed with grey bark which peels off in flakes of no particular shape, and form a large mound round the base of the tree. Owing to the smooth, scaling bark no climbing-plant hides the beauty of

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* (1) Notes from Australasia, II, The New Zealand Forests, *Journ. Arnold Arboret.*, vol. 2, pp. 232–36, Jan., 1922; (2) Northern Trees in Southern Lands, *Journ. Arnold Arboret.*, vol. 4, pp. 61–90, 1923.

the trunks, which stand out above the forest undergrowth like marble pillars in a vast cathedral."

But, short though the paper is, it is not descriptive merely, but touches on matters of particular importance, and advances theories concerning them. The first to be considered is the following statement: "Originally all the wetter parts where tree-growth was possible in New Zealand were covered with pure forests of Taxads and Conifers; but, save on the west coast of the South Island, and excepting the kauri in the North, these old types have long since been unable to compete successfully against the intrusion of the more modern broad-leaf trees. Even without the destructive intervention of the white man it is evident that in another five hundred years, perhaps, broad-leaf trees will have completely dominated the forests, and the Taxads and Conifers will virtually have become extinct over the greater part of New Zealand."

This theory, put forth quite independently by Wilson, and showing his power of rapid observation, is virtually identical with and confirmatory of my theory on the same subject published only a few months previously,* but it differs in some of the details. Thus I do not exempt *any* of the rain-forest associations, but, on the evidence of field notes, suggest that the taraire (*Beilschmiedia taraire*) is the climax succession of kauri forest, tawa (*B. tawa*) that of all other North Island rain-forests, and kamahi (*Weinmannia racemosa*) that of the rain-forests of the South Island and Stewart Island.

The procession of events in the colonization of New Zealand by forest as given by Wilson is as follows: "First in the dim and distant past, above the Mosses, Ferns, and other Cryptogams, rose the Taxads and the Kauri, soon to be followed by other conifers . . . For a period these trees, unchallenged, forested all the suitable land. Later came the broad-leaf dicotyledonous trees, the struggle for supremacy began, and to-day the broad-leaf usurpers hold the field." This, founded as it is on progressive phylogeny, differs fundamentally from my theory (*loc. cit.*, pp. 314, 315, 322, 323), according to which the most primitive trees were a combination of "the palaeozelandic and subantarctic elements of the flora now difficult to disentangle." Later came the palaeotropic element. According to change of climate with regard to temperature, so would these two elements move northwards or southwards. "The isolated colonies of *Nothofagus fusca* in the North Auckland district" point to a comparatively cold period, and "the presence of the tree-fern *Hemitelia Smithii* in the Lord Auckland's district suggests a warmer period." But to postulate the procession of events from the present composition and distribution of the vegetation is far from being a simple matter. If geology is correct, distribution must commence rather from mid-Tertiary times, when the land was reduced to a few quite small islands, than to the much earlier period when New Zealand was far larger than at present. Then, many land-movements, as also the glacial period, have greatly complicated matters. Nor do we know how long the present climax associations will remain stable. According to my recent observations, the mixed *Nothofagus*-taxad forest of Westland and western Nelson is apparently changing into pure *Nothofagus* forest; but, if so, will that climax endure during many generations?

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* *The Vegetation of New Zealand*, Leipzig, 1921, pp. 133, 134, 135, 139.

Another matter of particular interest dealt with is the function of the tubercles so common on the roots of the *Taxaceae*. The theory is advanced that "the tubercles are analogous with those on the roots of leguminous plants, and in all probability the bacteria break up the raw humic acids and convert them into readily available salts." Thus, "the tubercles are controlling factors in the rate of growth of the Taxads and Conifers of New Zealand." The chief argument given in support of this statement is that the above class of plants grow very slowly when planted in ordinary garden soil; "they merely linger, and their growth is very slow without the acid of the symbiotic organisms." Certainly—to take an extreme case—the rimu (*Dacrydium cupressinum*) varies greatly in its rate of growth when in cultivation, but this is correlated with climate rather than with soil, for in the rain-forest climate it grows in gardens probably quite as rapidly as in the forest. Certain taxads, too, grow frequently where humus is either wanting or in very small quantity. For instance, the totara (*Podocarpus totara*) occurs naturally on stony river-beds, the mountain-totara (*P. nivalis*) on deep stony debris in the subalpine belt, and the pygmy pine (*Dacrydium laxifolium*) on pumice with a thin layer of humus or in deep, wet peat—two quite different conditions. Nevertheless Professor Wilson has brought into prominence a most interesting line of research, which demands, for forestry reasons, a searching investigation. The tubercles are in enormous numbers. It is almost certain they must perform some important function in the economy of the plant.

The second paper appeals not so much to the botanical student as to those—increasing in numbers day by day—who are deeply interested in profitably growing trees for timber. It is, indeed, of great value to New Zealand forestry to have presented clearly the mature opinion of one so well qualified to judge of the relative value of various trees for afforestation purposes. Indeed, the paper must be studied in its entirety, for it gives precise details regarding the behaviour of a considerable majority of cultivated trees in New Zealand, Australia, and South Africa, together with information in some cases concerning their growth in their native habitats; and certain trees not in cultivation are recommended for trial. Incidentally, too, the correct names are used along with those incorrect but in general use.*

Perhaps the outstanding feature of the paper is the high value which Professor Wilson places on the insignis pine (*P. radiata*), and his opinion is thus summed up: "Over great areas in Australia, and only slightly smaller ones in New Zealand and South Africa, Insignis pine will yield three crops per century of merchantable timber of a class necessary for the development of the industries of these countries. Where it is found to flourish no more useful softwood tree can be planted in these southern lands. Its natural regeneration is good, and New Zealand is now the main source of seed-supply." I wonder what other tree can answer to the above description. Yet in this country it was generally despised until the late Mr. T. W. Adams, in season and out of season, urged that it should be widely grown, pointing out its extreme value. Were it hardy in Britain

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* For instance, the correct name, according to Wilson, of the following common trees is that in parentheses: *Pinus insignis (P. radiata)*, *P. laricio (P. nigra* var. *Poiretiana)*, *P. austriaca (P. nigra)*, *Abies Douglasii (Pseudotsuga taxifolia)*, *Larix europaea (L. decidua)*, *Abies excelsa (Picea Abies)*, *Cupressus Lawsoniana (Chamaecyparis Lawsoniana)*, *Betula alba (B. pendula)*.

and Europe it would rapidly become the leading tree for afforestation. I have recently seen it established by wind-borne seeds on mining tailings where the annual rainfall is 90 in., and in depleted Central Otago where the rainfall is about 18 in. and violent warm winds frequent.

The following notes from the paper under consideration regarding Professor Wilson's opinion of various (he deals with far more) exotic trees in New Zealand are well worth consideration :—

Pinus Pinaster : "Nothing to indicate that it is likely to become an important source of timber." Stone-pine (*P. pinea*) : "On parts of the Canterbury Plains it grows well and reproduces itself freely" ; but he also states that the tree, except in two places in South Africa, is not likely to be of importance. *P. canariensis :* "Gives little promise ; indeed, much of the country is too cold for it." *P. ponderosa :* "Does remarkably" on the Canterbury Plain and Otago, "and gives every promise of becoming a valuable tree for forest planting." Austrian pine (*P. nigra*, syn. *P. austriaca*) : "Except here and there in the drier parts of the South Island it must be considered a failure. In the Rotorua conservancy it is quite useless." Corsican pine (*P. nigra* var. *Poiretiana*, syn *P. laricio*) : "With *P. ponderosa* ranks after Insignis pine as the best variety for New Zealand . . . its rate of growth is only about one-half that of Insignis pine." Here again Mr. T. W. Adams's frequently stated opinion as to the great value of Corsican pine is supported. Bishop's pine (*P. muricata*) : "Save as a shelter or for ornamental purposes is of no value." *P. Torryana :* Wilson was surprised to see "magnificent trees" growing to a larger size than in their natural habitat in southern California. "At Rotorua the Government has a small plantation of this pine, and it is doing extremely well." *P. Coulteri :* "Good specimens were seen in the South Island." Douglas spruce (*Pseudotsuga taxifolia*, syn. *Abies Douglasii*) is dealt with at considerable length : "In some places it is very promising . . . The neighbourhood of Nelson seemed to me a promising place for this tree . . . I believe that Douglas Spruce will be found to grow well in many parts of New Zealand, but whether its wood will equal that from Puget Sound time alone can prove." Larch (*Larix decidua*, syn. *L. europæa*) : "Now that its requirements are understood, and if full discretion is displayed, it is probable that in New Zealand larch is destined to rank with *Pinus radiata* and *P. nigra* var. *Poiretiana* as the most useful of exotic trees for forest planting." Wilson is careful to point out it is a tree suitable for hill planting and not for the lowlands. *Picea Smithiana :* "On a private estate near Christchurch I saw fine individual trees." The Silka spruce (*P. sitchensis*) is recommended for experimental planting. *Picea* in general (syn. *Abies*) : "In New Zealand many other species of *Picea* have been planted, but none promise to be of value." *Abies* in general (syn. *Picea*) : As for *Picea* in general ; but good *A. pinsapo* and *A. Nordmanniana* were observed, also certain other species in what was left of Mason's garden, Wellington, especially *A. nobilis*, *A. alba* (syn. *A. pectinata*), *A. spectabilis* (syn. *A. Webbiana*), *A. venusta* (syn. *A. bracteata*). The Algerian *A. numidica* is suggested as "likely to succeed." Hemlocks (*Tsuga*) are "of no promise in the Antipodes" ; but in Mason's garden were fair *T. heterophylla* and *T. Mertensiana*, and at Queenstown (where there are fine trees of many species) the Himalayian *T. Brunnoniana*. Redwood (*Sequoia sempervirens*) : "Was nowhere favourably impressed with the suitability of this tree for forest planting," but "in the vicinity of Christchurch and

Nelson I saw fine trees . . . At Hanmer Springs, Canterbury, the Forestry Department have about five acres of this tree planted pure and doing well." *Cryptomeria japonica:* "Though it has been tried in many places it has not been a success." The deodar (*Cedrus deodora*), cedar of Lebanon (*C. Libani*), Atlas cedar (*C. atlantica*): "In New Zealand the species of *Cedrus* do well . . . On the Canterbury Plain the Deodar is most successful, but the Atlas Cedar does well . . . At Wellington both flourish, and grow much faster than the Lebanon Cedar." Macrocarpa (*Cupressus macrocarpa*): "It is as a hedge-plant that it is most widely employed . . . the species of *Cupressus* as yet have scarcely been employed for forest planting, but the fact that their wood is very lasting in the ground and therefore most suitable for fencing makes them valuable . . . As a group, *Cupressus* is a success in many parts of the Southern Hemisphere visited by me, and they have a decided future not only as ornamental trees, but as trees for forest planting; but before this can be embarked upon their nomenclature must be straightened out." *Chamaecyparis Lawsoniana* (syn. *Cupressus Lawsoniana*): This Wilson considers of little promise, but I recently noted very fine examples in western Nelson, so it may be useful in the wettest localities. *Libocedrus decurrens:* "In the old Mason garden, near Wellington, there are fine old trees . . . I saw none of special merit elsewhere." *Thuya plicata* (under name of *T. gigantea*): "There is nothing to indicate that the tree will be of value." *Juniperus virginiana:* "Does fairly well on parts of the Canterbury Plain." The oak (*Quercus robur*): "Many plantations, either pure or mixed with other northern broadleaf trees or with pines, have been made, but as a source of merchantable timber are an obvious failure." *Catalpa speciosa:* "In New Zealand alone millions of these trees were planted, but few survive, and none show any promise of growing into timber-producing size." Locust-tree (*Robinia pseudo-acacia*): "Does not promise to be of economic value." The London plane (*Platanus acerifolia*): "Does moderately well in certain parts of the South Island, but is not as happy as in Victoria and South Australia." The ash (*Fraxinus excelsior*): "In the southern parts of New Zealand it is possible, though I scarcely think probable, that the Ash may be useful in forest planting as a source of timber." Speaking of hard-wood trees generally, Professor Wilson is of opinion that *Eucalyptus* "is destined to supply the greater part of the world's future needs . . . For general construction purposes *Eucalyptus* timber will become more and more important."

In concluding, it is laid down that "it is only by experimental planting that the value of any tree can be determined"; and "where rainfall is sufficient the chemical properties of soils appear to be of much less importance than their physical characters." With this dictum, after many years' study of the vegetation of New Zealand, I am in full accord.

There is a brief account of the behaviour of southern trees in northern lands. Here it is rightly insisted upon that, except in specially favoured spots, very few New Zealand trees indeed can be grown at all; but for these favoured places surely far more species are available than Professor Wilson admits.

NATURALIZED ANIMALS AND PLANTS.

By Hon. GEO. M. THOMSON, M.L.C., F.L.S., F.N.Z.Inst.

THE publication of my book on *The Naturalization of Animals and Plants in New Zealand*, at the beginning of 1922, furnished an approximate record of all of each kind which had been introduced into the country, and of those which had established themselves. As stated in the introduction to the book, this is the only country of any size in which it was possible to make such a record. Having thus made a start, it is advisable to keep the record up to date as far as possible. I have therefore added here a few facts in reference to the animals already naturalized, and recorded some new introductions.

I take this opportunity also of noting a few errata which have unfortunately occurred in the text. The two most glaring, which alone I will refer to here, are printer's errors which neither the proof-readers nor I noticed until the book was issued. One is the heading "Carnivora," on pages 61 to 95 inclusive. On p. 75 the words "Order Rodentia" should have appeared above Family Sciuridae, and should have been on the page headings up to p. 95. Similarly, on p. 107 the words "Order Gralliformes" should appear above "Family Megapodidae," and be continued as the page heading up to p. 129, instead of "Anseriformes." It is remarkable how errors once overlooked may pass so frequently without correction. The blame for these two is largely my own.

The various animals of which mention has already been made in the book are referred to by page. Where new introductions are recorded, the approximate position where they should be placed in the scheme of classification adopted is also given by page.

MAMMALS.

COMMON SCRUB WALLABY (*Macropus ualabatus*) (p. 26).

There has of late been so much destruction of wallabies in the Waimate district that the number of these animals has been greatly reduced, and the Waimate Acclimatization Society, in September, 1922, asked the Minister of Internal Affairs to adopt protective measures, by declaration of a close season, &c., to prevent their extermination. The matter was duly considered, but "it was not considered desirable to bring them under the provisions of the Animals Protection and Game Act, as they might become a serious pest if protected." Where formerly they were in thousands they are now comparatively scarce, but they are not likely to be exterminated, though so greatly thinned out.

PIGS (*Sus scrofa*) (p. 33).

In the *Journal of Agriculture* for February, 1922 (vol. 24, No. 2), Mr. K. W. Gorringe, Instructor in Swine Husbandry, Live-stock Division, gives some interesting information as to the introduction of pigs into New Zealand, which is supplementary to mine. In regard to those pigs introduced

by Captain Cook in 1773 he says: "Records show that they were animals which he had procured from the natives at Tahiti — not brought from England, as is commonly supposed. Cook arrived at Dusky Bay in March, and remained there for some time. About the middle of the year, owing to scurvy among his crew, he sailed away temporarily to the Society Islands, where a supply of pigs was obtained. After his return to the New Zealand coast it is recorded that in October two boars and two sows were given by him to a chief at Table Bay, and one boar and two sows to natives in Queen Charlotte Sound. It is also recorded that Captain Furneaux, of the 'Adventure' (the other ship of Cook's Expedition), in June gave certain pigs to chiefs at Cannibal Cove, and others to natives at Cape Kidnappers. Other pigs must also have been liberated at various points."

DEER (p. 40).

A report on deer in New Zealand and the damage done by them in the forests and plantations, prepared by Mr. A. N. Perham, of the Forest Department, was laid on the table of the House of Representatives in the 1922 session of Parliament.

The author estimates that the number of deer of all species wild in the country at the present time amounts to about 300,000 head. They were introduced for sporting purposes, and only "0·005 per cent. of the population of the Dominion take part in the sport." The "estimated damage to mountain pastures, farm crops, fences, stock, displacement of stock, and damage to forests amounts to £180,000 per annum; estimated value of licenses, expenses incidental to sport, attraction of visitors, &c., amounts to £7,000 per annum: debit to the national interests of £173,000 per annum."

Mr. Perham considers that "the protection should be entirely removed from them in settled areas, otherwise many farmers will have to give up their occupation"; and that "the development of forestry will be an impossibility unless deer are eliminated in the areas affected." A few examples of the destruction wrought by them in pastoral areas are quoted. Dr. R. N. Adams, of Blenheim, in 1921 abandoned his grazing-run of 23,000 acres at Lake Rotoiti, Nelson; it was so overrun with deer that there was no feed left for stock. (These were presumably red deer.) Mrs. Woods, of Beaumont, lessee of the Blue Mountain Run, states: "I used to shear 10,000 sheep off the run, and carry 100 head of cattle on that portion known as Siberia. Last year I shore 6,500 sheep, and cannot now carry any cattle." The annual loss on this run (due to fallow deer) is estimated at £1,425. Mr. Perham gives other examples, both in pastoral and agricultural areas, but these will suffice.

In forestry operations great damage is also reported. In such a valley as that of the Hunter River the destruction of undergrowth is causing floods to be unusually heavy, and erosion to be much greater than formerly. In forests and plantations of exotic trees it is becoming increasingly difficult —as, for example, at Whakarewarewa—to do any planting. The young trees are being destroyed and the forest-growth put back. Mr. Perham states that he is "quite certain that the regeneration or replanting of the State's exotic plantations can never be accomplished if the presence of deer is allowed."

At the present time the Government has removed all restrictions from the shooting of deer in the Blue Mountains, so that the herds there will soon be greatly reduced. In regard to the red-deer herds in the Hunter Valley

and also in the Wairarapa very extensive culling is being carried out by the local acclimatization societies, so that the menace from the over-increase of these animals is being averted for the time being.

Sambur Deer (p. 49).—This species of deer is thriving and increasing in the Manawatu district. Like all new introductions into this country, the animals seem to grow to a great size, on account of the abundance of food. A head recently shot, and now in the possession of Mr. C. Whitehead, of Palmerston North, is claimed to be the largest Sambur head ever recorded. The antlers have a length of 36½ in., and a spread of 35½ in.

Wapiti (p. 49).—The wapiti introduced and liberated in Fiord County in 1905 appear to have increased very considerably, and are now not uncommon in the very difficult and almost inaccessible country at the head of George Sound and south to Caswell and Nancy Sounds. Messrs. V. Donald (of Masterton) and L. Murrell (of Manapouri) got three fine heads while investigating this region in the autumn of this year (1923). The largest was a 15½-pointer, with a length of 49 in., and a spread of antlers of 53 in.

White-tailed Deer (p. 50).—Mr. William Thomson, of Half-moon Bay, Stewart Island, writing me in February, 1923, says: "The white-tailed deer are now thoroughly established in the southern portion of Stewart Island, and it is only a question of time when they will wander all over it. . . . The only hope for the bush is to keep the deer well under control. Once their numbers increase beyond their food-supply, then good-bye to all ferns and small shrubs." At present the only plant which they are particularly thinning out is the common *Panax Colensoi*. They not only eat the foliage, but the young wood and the bark of this shrub, and so destroy it.

Moose (p. 50).—In 1910 ten moose were liberated in Dusky Sound, and they have increased and spread from there. During this last season they were seen and photographed by the Southland Acclimatization Society's ranger. Quite recently at the head of the sound Messrs. Donald and Murrell found indications of moose, with frequent traces of the young animals, and they saw a solitary cow.

BIRDS.

VIRGINIAN QUAIL, OR BOB-WHITE (p. 127).

The occurrence of this species in New Zealand seemed to be very doubtful in 1921. I could not obtain any definite information of its appearance later than 1902. In that year the Taranaki Acclimatization Society stated that these birds were steadily increasing, yet two years later it was said they had apparently all disappeared. They were also reported at the same time about Marton with young broods. The Auckland Society stated in 1909 that they had almost completely disappeared from that district. However, in the report of the last-named society for the year ending 31st March, 1923, we read that "during the winter the society caught a number of Virginian quail, or bob-whites, between Waingaro and the sea-coast, and these were liberated at the Cambridge Game Farm." So this species must now be added to those already naturalized.

I would suggest that in future each acclimatization society should prepare a list of the introduced birds found in its district, and that this list should be revised annually. It would prove a valuable and interesting record.

AUSTRALIAN SWALLOW (p. 150).

This species (*Hirundo neoxena*) is wrongly given as a form introduced from Australia. The error arose in the first instance from the proposal of the acclimatization societies to introduce Australian swallows into New Zealand. The species which has been introduced into this country, and which is referred to at p. 150, is the Australian tree-swallow, *Hylochelidon (Petrochelidon) nigricans*.

LINNET (*Linota cannabina*) (p. 171).

Up to the date of my book going to press there was no record of the occurrence of this bird, and I stated that "the failure of this species to establish itself in New Zealand is one of the most inexplicable problems in naturalization." As soon as the book appeared Mr. J. G. Myers, of the Agricultural Department, challenged the statement, and informed me that he had frequently seen the bird in the Wanganui district, and had collected the nests and eggs. This statement has since been verified by two competent observers, Mr. Johannes C. Andersen and Mr. H. Guthrie-Smith. The former reports the species as common in the Plimmerton district, and further states that he was very familiar with it in Canterbury during his boyhood. Mr. Guthrie-Smith states that "the brown linnet or grey linnet (*Linota cannabina*) exists in considerable numbers on or about the bush on the edge of the Taramakau (Westland) River bed. . . . Some years ago I believe I saw a travelling-party of the same species passing along the shore of Tutira Lake."

Mr. Myers, writing on the 15th March last, says: "I have seen them frequently in the Wanganui district, often at fairly close quarters, and once in the Wellington district. Linnets are shy birds, rather less sociable and very much less noisy than redpolls, and are, in my opinion, more easily overlooked than any other species, except perhaps the small rails."

BULLFINCH (p. 175).

This species has been recorded from two widely separated localities in New Zealand—viz., Hawke's Bay (in several places) and Catlin's district in southern Otago. These occurrences are given in the September (1922) number of the *N.Z. Journal of Science and Technology*, vol. 5, p. 230.

FISHES.

ATLANTIC SALMON (*Salmo salar*) (p. 193).

In my account of the attempts made to establish this fish in New Zealand waters, attempts which were commenced in 1864 and continued till 1911, I stated that "with the exception of two identifications recorded below, not a single authentic instance has been recorded of their return from the sea to the rivers. The fish has absolutely failed to establish

itself." This statement was quite true at the beginning of 1921, when my book went to print.

It is now of extreme interest to be able to report that the Atlantic salmon is definitely established in the South Island. The credit for this fine piece of naturalization work is certainly due to Mr. L. F. Ayson, Chief Inspector of Fisheries. He followed the method which he had already adopted so successfully in his efforts to naturalize the quinnat salmon—namely, that of confining his attention to one stream, which he stocked continuously with fry from imported eggs until the fish returned naturally to that selected stream.

In 1908 Mr. Ayson brought 150,000 eggs of Atlantic salmon from Canada, and these were hatched out in the Upokororo River, which flows into Lake Te Anau. Later in the same year 500,000 eggs from British rivers were obtained, followed in 1909 by another half-million. Lastly, in 1911, nearly a million eggs were imported from Europe. The great majority of all these shipments were taken to Lake Te Anau and hatched there.

In 1921–22 Atlantic salmon began to appear in the Upokororo and Eglinton Rivers, and during this past season they have become fairly common in the Waiau River, which drains the great western lakes. Mr. Ayson has now commenced to collect ova with which to stock the Wanganui River, in the North Island.

INSECTS.

I have to thank Mr. D. Miller, Entomologist to the Agricultural Department, for most of the information contained in the following list of recent introductions.

Order HYMENOPTERA.

(p. 273.) Family CHALCIDAE.

Nasonia brevicornis Ashm.

This parasitic wasp, which feeds on the pupae of the golden-haired blow-fly (*Pollenia stygia*) and of the greenbottle (*Lucilia sericata*), was specially imported from New South Wales in March, 1922, infested pupae having been received from Mr. W. W. Froggatt, New South Wales Government Entomologist. As the adult wasps hatched out they were distributed to five localities where sheep maggot-flies are particularly prevalent—viz., Timaru, North Canterbury, Blenheim, Hawke's Bay, and Whangarei. This species parasitizes the European bluebottle (*Calliphora erythrocephala*), the Australian greenbottle (*Pycnosoma rufifacies*), and the common house-fly (*Musca domestica*), in addition to the sheep maggot-flies.

Bruchophagus funebris Howard.

This parasitic wasp, first recorded by the Agricultural Department in 1921, was found by Mr. J. G. Myers in large numbers in clover-seed growing at Blenheim the previous year.

Rhicnopeltella eucalypti Gahan.

This Tasmanian gall-wasp is reported by the Agricultural Department in 1921–22 as destructive to blue-gums in several parts of New Zealand.

Habrolepis dalmanii Howard.

Recently Dr. R. J. Tillyard secured a consignment of this insect from Washington, and he is now making an attempt to establish the parasite in Christchurch, where the golden-oak scale is prevalent.

(p. 282.) Family VESPIDAE.

Vespa vulgaris Linn.

Specimens of the common European wasp, a most obnoxious and dangerous insect in its native land, were received by the Agricultural Department from Masterton. These specimens were found and sent in by Mr. Cumming, Agricultural Instructor, Educational Department, Masterton.

Polistes habraeus Fabr. The Fiji hornet.

The first record of this species is labelled "North Auckland, October, 1921," and no doubt came from Henderson or its vicinity, as at that time Mr. Miller was engaged in an investigation in that district. Another specimen was picked up on the pavement of Queen Street, Auckland, in November, 1921. This last specimen had probably escaped from a consignment of island fruit.

Order COLEOPTERA.

(p. 286.) Family NITIDULIDAE.

Carpophilus aterrimus.

This beetle was recorded in 1921–22 from water-chestnuts imported from China. It is, however, a common species, and frequently infests dried fruits.

(p. 291.) Family PTINIDAE.

Lasioderma sericorne Fabr. The cigarette-beetle.

This species has been bred by the Agricultural Department in 1921–22 from dates imported from Asia. It is widely distributed, and attacks tobacco and stored fruits.

(p. 297.) Family CURCULIONIDAE.

Elytroteïnus subtruncatus Frm. The Fiji lemon-weevil.

This weevil, which occurs in the Cook Islands, was introduced into New Zealand in June, 1922, in two consignments of lemons landed at Lyttelton. There is no record of its having spread from any of the ports to which Cook Island fruit comes.

Order LEPIDOPTERA.

(p. 305.) Family TORTRICIDAE.

Eucosma plebiana Zell. Eucalyptus-bud moth.

Reported by the Agricultural Department, and identified by Mr. Philpott, of the Cawthron Institute, in 1921–22. It is very abundant

on young growth of gum-trees, the larvae eating and tying the leaves together.

Order DIPTERA.

(p. 315.) Family MUSCIDAE ACALYPTRATAE.

Dacus passiflorae Froggatt.

Reported by the Agricultural Department in 1921–22 as occurring in oranges imported from Sydney.

(p. 317.) Family ANTHOMYIIDAE.

Ophyra analis ; Ophyra nigra.

The Agricultural Department in 1921–22 reported the larvae of these Australian moths as frequently found associated with the larvae of maggot-flies on sheep's wool.

(p. 319.) Family MUSCIDAE.

Pycnosoma rufifacies Froggatt. Australian greenbottle.

Reported by the Agricultural Department in 1921–22 as well established in the North Island, where it occasionally blows sheep.

Suborder HOMOPTERA.

(p. 328.) Family CICADELLIDAE.

Typhlocyba australis Froggatt. Apple-leaf hopper.

I mentioned the fact (at p. 561) of the introduction of this insect from Australia, but without any information as to its range. In the *Proceedings of the Linnean Society of New South Wales*, 1921, vol. 46, part 4, Mr. J. G. Myers gives an account of the insect, and states that it inflicts considerable damage on the foliage of apple and hawthorn. Its range in New Zealand is Canterbury, Nelson, Hawke's Bay, and Auckland.

(p. 329.) Family APHIDIDAE.

Aphis bakeri Cowen. Clover-aphis.

Mr. J. G. Myers, in the *Journal of Agriculture*, reported this North American species in 1921–22 as occurring frequently in clover-seed. "Through the agency of the honey-dew exuded by the insect the seed is glued together in lumps of varying size."

(p. 333.)

Aspidiotus epidendri Bouché.

Reported by the Agricultural Department in 1921–22 as infesting palms at Hastings, Hawke's Bay.

Aspidiotus rapax Comstock.

Reported by the Agricultural Department as occurring on various plants. It is very common in New Zealand.

(p. 333.)

Chrysomphalus aurantii Mark. Red scale.

The Agricultural Department in 1921–22 reported this scale on oranges imported from Melbourne. It is a serious pest on citrus in the Tauranga district.

(p. 338.) Suborder ANOPLEURA.

Linognathus stenopis Burm. Goat-louse.

Reported in 1921–22 by the Agricultural Department as having been found on a young goat.

Order ACARINA.

Family ERIOPHYIDAE.

Eriophyes tristriatus Nal. Walnut-leaf blister-mite.

Specimens of this mite were received by the Agricultural Department in 1921–22 from Dunedin and Christchurch, where it was found on the leaves of walnut-trees.

(p. 346.) Family TYROGLYPHIDAE.

Rhizoglyphus echinopus Fum. et Rob. Onion-mite.

Recorded by the Agricultural Department as occurring on onions in Christchurch. This species, which was introduced from Europe, has been in New Zealand for many years, though not reported before. (A species of *Rhizoglyphus* was also found on hyacinth-bulbs imported from Holland.)

(p. 349.) Family TETRANYCHIDAE.

Schizotetranychus mytilaspidis Harvey. Citrus red spider.

The Agricultural Department reported this mite in 1921–22 as occurring on lemon-trees at Gisborne.

Family EUPODIDAE.

Notophallus bicolor Frogga t. Blue oat-mite.

This Australian species did considerable damage to crops of Algerian oats in South Canterbury in 1921–22.

CRUSTACEA.

FOREIGN SHRIMPS.

Formerly nearly every fresh-water stream and lake in New Zealand abounded with shrimps (*Xiphocaris curvirostris*), but wherever trout have been introduced and have thriven they have greatly reduced the abundance of these Crustacea, and in many cases have nearly exterminated them. Attempts are now being made to introduce foreign species, but, unfortunately, those who control acclimatization societies never take the trouble to consult scientific experts. We have in New Zealand one of the most eminent authorities on Crustacea in the world, in the person of Dr. Charles Chilton, Rector of Canterbury College and Professor of Biology; yet even in

Christchurch the local society tried an experiment in restocking their streams with crustacean food for their fishes without ever consulting this expert. The following is copied from the local papers of February, 1922 :—

"In December, 1920, about five thousand shrimps caught in the tidal waters of the Ashley River were placed in a race in the Acclimatization Society's gardens in Christchurch, in order to ascertain if they would increase when they were transferred to waters other than their natural spawning-places. Most of the shrimps placed in the race had eggs attached. After they had been in the race for more than a year Mr. D. Hope, curator, ran off the water and examined the pools. He found that there were considerable numbers of shrimps, but all except one appeared to be young, the original stock having almost completely disappeared. The result of the experiment, Mr. Hope reported to the Council of the Acclimatization Society, showed that the shrimps certainly would spawn in fresh water, although their natural spawning-place was in tidal water or within a short distance of water influenced by the tide. The almost complete disappearance of adults from the race seemed to point to the fact that they required tidal water in which to increase. He suggested that the young shrimps should be kept in the race for another year in order to ascertain if they spawned or died. Mr. M. H. Godby said that the adult shrimps probably had escaped from the race, and had not died. Mr. E. F. Stead said that the experiment was a very important one, as shrimps, if they increased in fresh water, would be valuable food for trout. It was somewhat strange that shrimps were present in some Canterbury rivers but not in others. In the rivers in which they were present trout were exceptionally large, and had good pink flesh. The object of the experiment was to discover if rivers not frequented by shrimps at present could be stocked with them in order to provide additional food-supplies for trout. The Council agreed with Mr. Hope's suggestion that the experiment should be continued."

As the fresh-water shrimp (*Xiphocaris curvirostris*) occurs right down to the brackish water of all streams affected by tidal water at their mouths, and, as far as is known, spawns throughout their length, all that the society is doing is to attempt to reintroduce this species into streams which have been already denuded of them by trout. It is all right to try the experiment, but it is absurd to imagine that they are making any new discoveries. The Otago Acclimatization Society has introduced another species from Victoria.

CRUSTACEA DECAPODA.

(p. 341.) Family ATYIDAE.

Xiphocaris compressa de Haan.

This Australian fresh-water shrimp was introduced into New Zealand by the Otago Acclimatization Society in 1922 for the purpose of furnishing a food-supply for trout. It is very closely allied to the common New Zealand species, differing only in the characters of the rostrum. At least two lots have been received.

The latest suggestion of this kind comes from the Auckland Acclimatization Society, which is considering the advisability of introducing a fresh-water prawn from Samoa (the species is apparently unknown to the society) as food-supply for trout.

A RARE RIBBON-FISH TAKEN IN NEW ZEALAND WATERS.

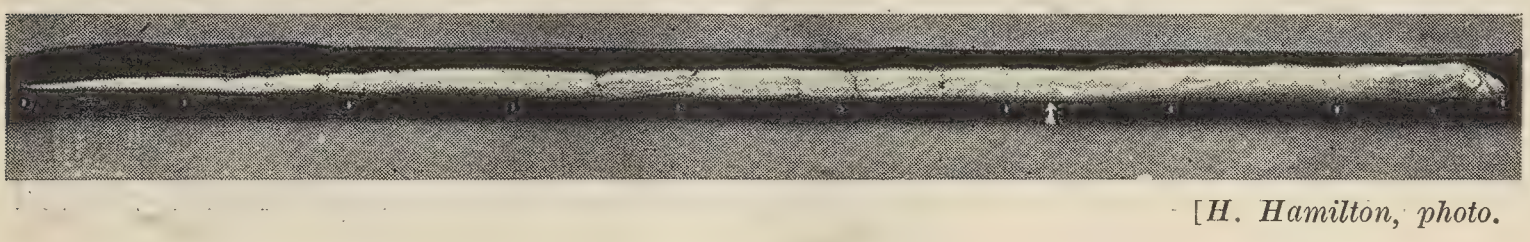
By W. J. PHILLIPPS, F.L.S., F.R.G.S.

Order ALLOTRIOGNATHI (Rainbow-fishes). Family REGALECIDAE.

IN December, 1919, a ribbon-fish was secured by Mr. Hart, of the Cape Palliser Lighthouse. The head and tail were fortunately preserved, and at a later date, through the courtesy of Mr. L. F. Ayson, presented to the Dominion Museum.

As it differed from any Trachipteridae listed by Hutton, 1904, in *Index Faunae N.Z.*, or by Waite, 1907, in *Basic List of N.Z. Fishes*, the ribbon-fish was at first regarded as new. However, it was later found to be identical with a fish, *Regalecus parkeri*, secured in the Otago Harbour, and described by Dr. W. B. Benham in *Trans. N.Z. Inst.*, vol. 36, p. 198. This article evidently appeared too late for inclusion in Hutton's list, and possibly on this account was overlooked by Waite, 1907 (*loc. cit.*).

In July, 1921, Mr. Fleming, manager of Turnbull and Jones, Wellington, presented to the Dominion Museum a ribbon-fish which proved on comparison to be identical with the Cape Palliser specimen. The ribbon-fish



[*H. Hamilton, photo.*

FIG. 1.—*Regalecus parkeri* from Island Bay.

was secured at Island Bay, stranded in a rock-pool. It was still alive, and secured with difficulty, but did not reach the Museum until two days after its capture.

The specimen figured measured approximately 9 ft. in length, or 2,766 mm., when first secured. The depth just posterior to the nuchal crest is equal to nearly half the head or a little over twice the diameter of the eye. The body is compressed, depth being 2·8 times thickness. Body is of an unusually elongate form, being $22\frac{1}{2}$ times the length of head; nearly 42 times the greatest depth, taken at nuchal crest; and 45 times the depth at vent, the position of which is marked with an arrow. Benham (*loc. cit.*), p. 200 (footnote), records a second specimen from Stewart Island in which the length is 43 times the depth.

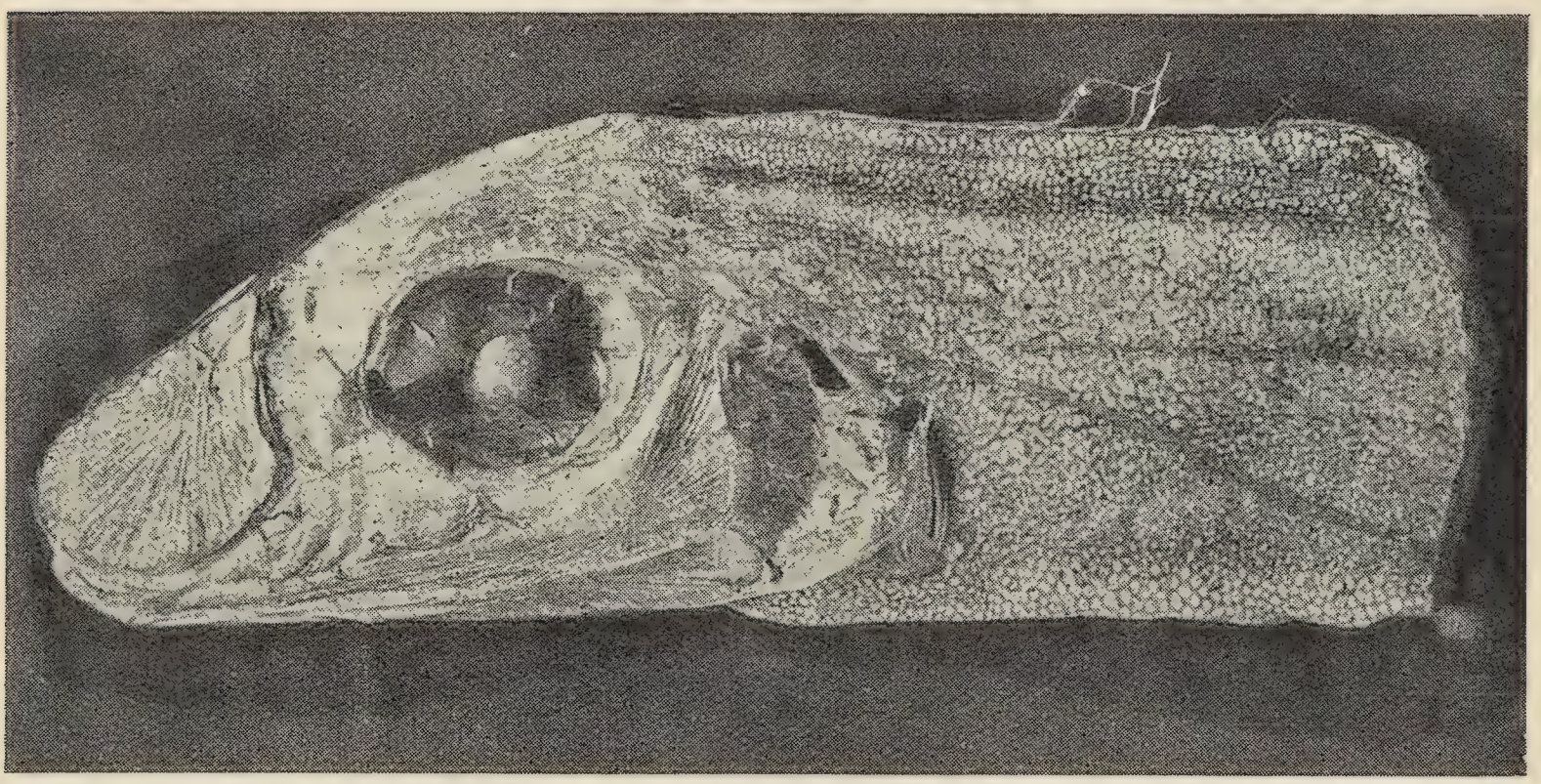
Teeth: The Island Bay specimen has 7 teeth on a crest on the vomer, 2 of which appear rudimentary. There are also 3 teeth on the outer margin of the lower jaw. The Cape Palliser specimen has 5 teeth on the vomerine crest, and 2 on each side of the outer margin of the lower jaw.

Fins: On arrival it was found that the Island Bay specimen had 384 dorsal rays or stumps of rays. The dorsal commences on the nuchal crest in what may have been a number of long filaments, though these are not present in examples to hand. The caudal fin is absent. Minute depressions, apparently for the insertion of a single filament, may be

seen on the ventral surface a little posterior to the insertion of pectorals. Pectorals inserted, as in *Regalecus*, below the posterior margin of the gill-cover on side of body, there being 9–10 pectoral rays.

Colour: The whole of the body is covered with a thick coating of minute silvery specks, shown under the microscope to consist of large numbers of minute crystalline prisms. The colour is slightly darker on the dorsal surface. The fins of the Island Bay specimen were scarlet when first secured.

The figure below is a view of the head of the Cape Palliser specimen nearly $\frac{3}{4}$ natural size. All bones of the head are radiatingly ridged. The operculum is extended downwards and backwards, with suboperculum below it. The snout is protractile, and when extended increases the length of the head by $\frac{1}{4}$. The nostrils are placed, one on each side, in



[*H. Hamilton, photo.*

FIG. 2.—Head of *Regalecus parkeri* from Cape Palliser.

front of the eye, on level with the upper margin. The eye is large, being $\frac{1}{4}$ the length of the head. The gill-opening reaches forward to the vertical under the middle of the eye.

The commencement and oblique drop of the lateral line towards the ventral surface is evident in the above figure. The lateral line continues along the side to tip of tail, being situated ventrally on the side about $\frac{1}{8}$ of the total height of body. Examination showed it to be a raised tubular structure.

A note supplied with the Cape Palliser specimen gave the extreme length of the fish as 8 ft. 9 in., greatest width $2\frac{1}{2}$ in., greatest thickness 1 in.

SCIENTIFIC RESEARCH IN NEW ZEALAND.

Report on the Activities of the Various Organizations, Government Departments, and Private Individuals conducting the same.

By J. ALLAN THOMSON, D.Sc., Director of Dominion Museum, and Hon. GEO. M. THOMSON, M.L.C., F.L.S., F.N.Z.Inst.

PART I.—GENERAL.

SHORTLY after the commencement of the Great War the Government of New Zealand was invited by the British Government to set up an organization for the co-ordination of scientific and industrial research. In spite of considerable discussion by scientific bodies, ending in definite recommendations to the Government by the New Zealand Institute and the National Efficiency Board, no official action has been taken, beyond placing at the disposal of the New Zealand Institute a small sum of money for grants to research workers. There is no co-ordination of research at present in this Dominion.

There is, however, a good deal of research being carried on by several Government Departments, by the Cawthron Institute, the Portobello Marine Fish-hatchery, the Polynesian Society, and by many private workers, as well as by the University colleges and schools of mines and agriculture. The principal Departments whose officers are engaged in such work are the Department of Agriculture, the newly constituted State Forest Service, the Geological Survey, the Dominion Laboratory, the Dominion Museum, the Department of Mines, Meteorological Department, and branches of the Survey and Railway Departments. The electrical branch of the Public Works also does research work.

Of non-official bodies the New Zealand Institute is the recognized medium for research work, which is subsidized by the Government. The funds supplied for this purpose are voted by Cabinet, and are allocated by a committee, set up for the purpose, to research workers recommended by the various affiliated branches of the Institute. Practically all the research workers are members of the New Zealand Institute, and a considerable part of the researches are published in the *Transactions* of the Institute, or in the *Journal of Science and Technology*. The Board of Science and Art, to which this report is made in the first instance, does not itself conduct or subsidize scientific research, but it assists indirectly by publishing, or recommending for publication, the results of such work, in the form of bulletins and manuals, or in the columns of the *Journal of Science and Technology*.

The Cawthron Institute, founded in Nelson by the bequest of the late Thomas Cawthron, is purely a research body, and its officers are engaged in soil survey, chemical examination of the waxes, oils, and resins of New Zealand, and especially in the examination of entomological, mycological, and bacteriological questions bearing on the fruitgrowing industry.

The Portobello Marine Fish-hatchery does a limited amount of research work in problems connected with the exploitation of the marine wealth of the seas round New Zealand.

The four University colleges are doing a certain amount of scientific research, chiefly by senior students, working in conjunction with their professors. A few of these students are holders of research scholarships.

A good deal of all this outside work is linked up with and assisted by the New Zealand Institute.

As is only to be expected where there are so many workers and so little co-ordination, there is a certain amount of overlap in the work undertaken, but not to any serious extent. Just to take one example: The Department of Agriculture, the Dominion Museum, the Cawthron Institute, and several private workers are doing valuable entomological research. It would almost certainly conduce to more efficiency if all these individual workers could either meet from time to time and agree as to certain lines of work which it was desirable to carry out, or if some organizing body could recommend the lines on which such research was most wanted.

Although many important industries in the Dominion employ the latest scientific methods, there is great room for improvement in others, and the questions of dealing effectively with by-products and waste materials require greater consideration than they have yet received. In drawing up this report it has not been found possible to get much information from those engaged in such staple industries as meat-freezing, butter- and cheese-making, &c. It is probable, however, that this report may act as a basis on which to build in succeeding years a fuller and more adequate presentation of the subject, and that manufacturers, realizing the importance of research, may unite with the Government and the various scientific organizations to secure more efficient and economical working. This is a matter which might well be taken up by Chambers of Commerce and manufacturers' associations throughout the Dominion.

PART II.—SPECIFIC.

The different bodies engaged in scientific research have mostly furnished the details of their work, which is here summarized.

I. NEW ZEALAND INSTITUTE.

The following researches, aided by funds from the Research Grant Committee, have been carried on during the past year, and some are still in progress.

Dr. C. E. Adams, Government Astronomer, is engaged in continuous research at the Hector Observatory, Wellington, in the following directions: (*a*) Research on the position of the moon; (*b*) photographing the moon and stars on the same plate; (*c*) full records of all sunspots (assisted by Mr. R. C. Hayes); (*d*) occasional observations of occultations.

Professor P. W. Burbidge, Professor of Physics, Auckland University College, is carrying out a record of the intensity of long-wave radio-signals from Europe. Mr. G. M. Salt, M.Sc., is associated with Professor Burbidge in this research.

Dr. Kathleen Curtis, Cawthron Institute, Nelson, has worked during the past year on black-spot of the apple and pear. The study of these

diseases has already yielded results which are of great value in the advisory work of the Institute. This year her work on the brown-rot of stone-fruits has been resumed.

Dr. W. P. Evans, late Professor of Chemistry, Canterbury College, reported in December that experimental work had been carried out by himself and three assistants as follows: (*a*) Ultimate analyses of and distribution of sulphur in twenty-nine samples of coal from the South Island; (*b*) leaching experiments on three typical coals, with special reference to the change in ash; (*c*) examination of a coal-resin from Central Otago. A general account of the work was presented to the meeting of the Australasian Association for the Advancement of Science at Wellington in January, and arrangements are being made for the publication of various portions of the research in scientific journals.

Dr. C. Coleridge Farr, Professor of Physics, Canterbury College, has been engaged for five years—in conjunction with Mr. H. E. Philpott, of the testing staff of the Public Works Department—in a research on the porosity of porcelain insulators. The origin of this research was the failure of certain insulators on the Lake Coleridge transmission-line. The results were published in the *Journal of the American Institute of Electrical Engineers* of 8th October, 1922. The paper has called forth most favourable comment from experts elsewhere. Mr. Evan Parry, late Chief Electrical Engineer of the Dominion, writing from London to Mr. L. Birks, his successor in this important position, says: "The results are very important, and, what is more, are very much more conclusive than any that have hitherto been published." The work has now become of such a practical nature, and partakes so much of routine, that it is suggested by the New Zealand Institute that it should be taken up by the Public Works Department, as it has passed out of the experimental stage, and has become of commercial importance.

Dr. Farr is now engaged on a research on the properties of gas-free sulphur.

Dr. J. Malcolm, Dean of the Medical School and Professor of Physiology, University of Otago, has been conducting a series of researches for four years on the food value of certain New Zealand fishes. Two papers on the subject have already been published in the *Transactions of the New Zealand Institute*, and a third is now being printed.

Dr. Malcolm is also engaged on a research on the pharmacology of New Zealand plants.

Dr. E. Marsden, lately Professor of Physics, Victoria College, now Assistant Director of Education, has been conducting two researches recently, viz.:—

(1.) An investigation of the recent earthquakes at Lake Taupo. This has involved the construction of three seismometers at Wairakei, and the working-up of several hundred earthquake records as regards amplitudes, periods, and time of various phases of quakes. He has made records of subsidences north of Taupo which probably caused the earthquakes. He has also made arrangements to follow the movements and quakes by installing seismographs at Taupo, and arranging tide-gauges to be placed round the lake.

(2.) A research on the effect of *a* particles on matter. A preliminary account has been accepted for publication by the *Journal of Atmospheric Electricity and Terrestrial Magnetism*. A fuller account is in progress, and

will be submitted when certain comparative measurements have been made at Apia, Samoa.

Mr. D. D. Milligan has undertaken a research on the New Zealand Orthoptera, which is now in progress.

Professor R. Speight, Professor of Geology, Canterbury College, has been making a geological survey of the Malvern Hills district, with special attention to their economic possibilities. He reported in November last that the examination of the area had been continued as occasion offered. Special attention had been paid to the south-west part of the area, and it was hoped by the end of 1923 a definite report on the geology would be available. The investigations carried on revealed no results of special commercial value, except the possibility of the existence of a fair amount of coal in the Glenroy area. The new mine opened a little while ago near White Cliffs turned out much better than expected, and there is now a considerable amount of coal in sight, and the promise of the existence of a valuable area of brown coal in a workable seam or seams within reasonable distance from rail.

Dr. F. W. Hilgendorf, Lincoln Agricultural College, is continuing the observation of artesian wells in the Canterbury District. This research has been carried on for twelve years, the object being to find causes of fluctuations, and the sources of supply. Four continuous recorders are running, along with an evaporometer.

Hon. G. M. Thomson and Mr. G. Stuart Thomson, B.Sc., have just concluded a research on the economic value of "whale-feed" (*Munida gregaria*), which has not yet been published. This crustacean occurs in enormous quantities in the New Zealand seas during several months of the year. The research was undertaken to find—(1) The quantity of oil present in these Crustacea; (2) the nitrogen content; and (3) the percentage of phosphoric acid. As the result of numerous analyses made at various seasons it was considered that it would very seldom pay, under present conditions of labour, to collect these shrimps for their oil or their manurial value. They constitute one of the most important forms of fish food in these southern seas, but the cost of handling them would be prohibitive.

Mr. A. M. Wright, chief chemist to the New Zealand Refrigerating Company, has been investigating the vitamine content of commercial meat products. In his report of December last he states that the investigation had been carried on during the past year with a view of determining the reliability of the growth of yeast in pure cultures as a method of estimating the vitamine B content of foodstuffs. The method employs yeast instead of animals as the test organism in the determination of vitamine B. A number of modifications have been the subject of experimental study, and one gives promise of yielding satisfactory results. No publication of results has yet been made; the earlier 1921 results have been the subject of various lectures and demonstrations, popular accounts of which have appeared in various newspapers.

Professor T. H. Easterfield, Director of the Cawthron Institute, Nelson, has recently completed an investigation dealing with the mineral oils of New Zealand. A paper embodying the results of this research will shortly be submitted to the *Journal of the Society of Chemical Industry*. He is also engaged on a research on orchard-fruits.

Mr. William C. Davies, Cawthron Institute, is conducting a research on soil bacteria and protozoa.

II. CAWTHRON INSTITUTE OF SCIENTITIC RESEARCH.

(Dr. THOMAS H. EASTERFIELD, Director.)

Entomology :— BIOLOGICAL DEPARTMENT.

The following researches are being carried out in this branch :—

Dr. R. J. Tillyard, assisted by Mr. A. Philpott :—

(1.) Distribution of *Aphelinus mali* (parasite of the woolly aphis) throughout New Zealand.

(2.) Study of the grass-grub problem in New Zealand, especially with a view to controlling the pest by introduction of natural enemies.

(3.) Testing of new chemical substances which act as repellants of injurious insects.

Dr. R. J. Tillyard, assisted by Mr. Gourlay :—

(1.) Introduction and distribution of *Habrolepis dalmanni* (parasite of oak-scale) in the Christchurch district.

Dr. R. J. Tillyard :—

(1.) Introduction and distribution of *Digonochaeta setipennis* (parasite of the European earwig) into Teviot and Central Otago districts.

(2.) Study of fossil insects.

(3.) Systematic and life-history work on various orders of insects in New Zealand.

Mr. A. Philpott :—

(1.) Systematic and life-history work on New Zealand Lepidoptera.

Mr. C. Gourlay :—

(1.) Systematic and life-history work on New Zealand Hymenoptera.

Mr. D. D. Milligan :—

(1.) Systematic and life-history work on New Zealand Orthoptera.

M. A. L. Tonnoir :—

(1.) Systematic and life-history work on New Zealand Diptera.

Mycology :—

Dr. Kathleen Curtis is engaged on—

(1.) Investigation on *Sclerotinia cineria* and various species of *Venturia.*

(2.) Hop-root disease.

Miss Jean Murray :—

(1.) Leaf and twig diseases of the willow.

(2.) New Zealand fungi.

CHEMICAL AND AGRICULTURAL DEPARTMENT.

The following researches are in progress :—

Professor Easterfield : Researches on *Phormium tenax.*

Mr. T. Rigg, together with Messrs. L. Tiller and J. A. Bruce :—

(1.) Soil survey of the Nelson Province.

(2.) Improvement of poor soils.

(3.) Utilization of different types of soil for the growth of lucerne.

(4.) Utilization of land recently reclaimed from the sea.

(5.) Special manurial experiments on fruit and tomatoes.

(6.) Study of Maori agriculture.

Mr. N. McClelland with Mr. L. Tiller: Researches on orchard sprays and cool storage of fruit.

Mr. W. C. Davies: The bacteria and protozoa of certain New Zealand soils.

III. PORTOBELLO MARINE FISH-HATCHERY.

(Mr. Wallace Adams, Curator.)

The work of this biological station, the only one south of the Line, is largely in the nature of continuous research, in which the Hon. G. M. Thomson, Chairman of the Board, and Mr. M. Young, the Biologist, assist. The following investigations have been undertaken during the past year, several of which are a continuation of former work:—

(1.) Record of the food of all species of fish taken by the trawl, by seine nets, or by line (by examination of their stomach-contents).

(2.) Rate of growth of certain species of fish confined in the hatchery-tanks (by measurements taken every month).

(3.) Collection weekly and examination of surface tow-nettings made in the immediate vicinity of the station.

(4.) Culture of the southern rock-oyster (*Ostrea tatei*).

(5.) Observation of ocean currents.

An experiment was commenced at the beginning of 1920 by liberating drift-bottles from time to time off Otago Heads. The last lot were liberated in May, 1922; but the contained labels continue to arrive by post. Altogether 484 bottles were sent adrift, and apparently every one drifted north, not a single one having been picked up south of the Heads. Up to the 31st March, 1923, a total of sixty-seven bottles (or 13·8 per cent.) have been returned, mostly from the coast to the north-east, and as far north as Cape Turnagain, and through to Nelson Bay. Four have been picked up on the Chatham Islands.

Special researches in connection with the hatchery have been carried on during the year:—

(1.) Hon. G. M. Thomson and Mr. G. Stuart Thomson, B.Sc., have investigated the economic value of "whale-feed."

(2.) Mr. C. Raynor Bell, Professor of Clinical Dentistry, University of Otago: Investigation on the development and histology of the teeth of various fishes belonging to the families Gadidae, Labridae, Sparidae, Ophididae, Parapercidae, Carangidae, &c. The fresh material essential for such research was obtained and preserved at the hatchery. Professor Bell says: "In the course of my work I have been able to recognize developmental phenomena which, traced through their evolution to the mammalia, appear to have a definite bearing on the potentialities, tendencies, and aberrations of the tooth-germs of man."

(3.) Mr. H. J. Findlay, M.Sc., is working out the occurrence and distribution of the Mollusca of Otago Harbour.

IV. UNIVERSITY COLLEGES.

A considerable amount of the research work carried on at the four University colleges is in the form of investigations undertaken not for research purposes, but as bases for the theses required for the higher Science degrees. It is, however, difficult to draw the line at researches taken up purely for their own sake or their economic importance, and

those which are only intended as qualifications for a degree. The latter frequently have no present economic value. It has therefore been decided to include all such researches in this series.

1. AUCKLAND UNIVERSITY COLLEGE.

A. *Physics Department.*

The following researches are now being carried on :—

(1.) Professor P. W. Burbidge and Mr. G. M. Salt, M.Sc. : A record of the intensity of European radio-signals.

(2.) Mr. E. H. R. Green, M.Sc. : The variation of intensity of radio-signals with distance.

(3.) Mr. G. H. Munro, B.Sc. : The effect of the day and night line on radio direction-finding.

(4.) Mr. J. F. Simpson, B.Sc. : An instrument to measure feeble alternating currents.

B. *Geological Department.*

Professor J. A. Bartrum is engaged on the following problems :—

(1.) Examination of the Tertiary beds between Riverhead and Kaukapakapa, in the Auckland District.

(2.) The distribution and petrographic content of bands of conglomerate in Tertiary and earlier beds which contain igneous and metamorphic rocks unrepresented at present, as far as is known, *in situ* in the Auckland District.

(3.) Report on the igneous rocks of the Whangarei and Bay of Islands district.

This work was undertaken for the Geological Survey, to which Department the account of the work done has been handed for publication.

C. *Chemical Department.*

The following researches are being carried on by Professor F. P. Worley, Mr. W. F. Short, and senior students :—

(1.) Action of alkali cyanides on gold and silver.

(2.) Action of acids on metals.

(3.) Surface tension of solutions.

(4.) Relationship of polyvalent elements.

(5.) Essential oils of manuka (*Leptospermum scoparium*).

(6.) Essential oils of *Phebalium nudum*.

(7.) Chemistry of the products of the kauri-tree (*Agathis australis*).

(8.) Introduction of the chloromethyl group into the aromatic nucleus.

(9.) Modification of Gabriel's reaction.

(10.) Influence of salts on the phytosynthesis of sugars.

D. *Biological Department.*

(1.) Professor J. C. Johnson :—

(*a.*) An ecological survey of Rangitoto Island (assisted by Miss B. Battesby).

(*b.*) The lianes of New Zealand.

(*c.*) Effect of histological fixatives on cell-contents.

(*d.*) Observations on *Rhipogonum scandens* (assisted by Miss A. Tizard).

(*e.*) Preliminary observations on—(i) Embryology of *Homothrix* ; (ii) Plankton and marine algae in the vicinity of Auckland ; (iii) fatigue and its results in adults and school-children (assisted by Mr. W. H. Entwistle).

(2.) Mr. T. L. Lancaster, Assistant Lecturer in Botany :—
  (*a.*) The pneumatophores of *Eugenia maire*.
  (*b.*) Observations on increase in diameter of the kauri-tree (*Agathis australis*).

(3.) Mr. W. R. McGregor, Demonstrator in Biology :—
  (*a.*) A report, involving five years' research work, on forest problems in New Zealand (for the State Forest Service).
  (*b.*) Other researches on forest ecology, histology of wood, and on soil-analysis.

(4.) Mr. Gerard Maskell, B.Sc. : A survey of Orthoptera in the vicinity of Auckland.

(5.) Mr. R. C. Wilson, B.Sc. : The mycorrhiza of New Zealand plants.

(6.) Miss Jeanie Hume, M.A. : Phylloclades of New Zealand Leguminosae.

(7.) Miss Valeria Johnson, M.A. : Ecological study of northern heathlands of New Zealand.

(8.) Miss Joyce H. Wilson, M.A. : Crevice-plants—an ecological study.

(9.) Miss Madge Crookes, M.A. : Juvenile forms of New Zealand plants.

(10.) Miss Gweneth Burrow : New Zealand dwarf tree-ferns.

E. *School of Engineering.*

Mr. S. E. Lamb, B.Sc. (Director), and Mr. E. J. McLaren are engaged on economic research problems on New Zealand timbers for the State Forest Service.

2. VICTORIA UNIVERSITY COLLEGE.

A. *Biological Department.*

The following researches are in progress in this department :—

(1.) Professor H. B. Kirk : Histology of the New Zealand Coniferae (in connection with the State Forest Service).

(2.) Mr. J. S. Yates, M.Sc. : The root-nodules of conifers and other trees.

(3.) Mr. R. Grimmett, B.Sc. : The Cryptozoa of certain plant associations.

(4.) Mr. J. G. Myers, B.Sc. : The cattle-tick (in connection with the Department of Agriculture).

(5.) Miss Aline Joyce, M.Sc. : The morphology and life-history of *Aplysia tryoni*.

(6.) Miss Ellen Pigott, M.A. : The embryology of *Corynocarpus laevigata*.

(7.) Mr. A. Morris Jones : On the minute structure of the timber of the New Zealand beeches.

B. *Chemical Department.*

The following researches are being carried out under the direction of Professor P. W. Robertson :—

(1.) Mr. A. D. Munro : The nature of nitrogen sulphide.

(2.) Mr. W. A. Joiner : Unsaturation in certain citraconic-acid derivatives.

(3.) Mr. H. L. Richardson : Adsorption by charcoal in phenol solution.

(4.) Mr. V. A. Reader : The kinetics of bromine substitution.

3. CANTERBURY UNIVERSITY COLLEGE.

The following are the researches being carried on by the various scientific departments :—

A. *Physics Department.*

(1.) Professor C. C. Farr and Dr. D. B. Macleod :—
  (*a.*) Testing of porosity of insulators.
  (*b.*) A research on the viscosity of sulphur (a preliminary account has been published in *Proceedings of the Royal Society of London*, vol. 97, 1920).

(2.) Dr. D. B. Macleod :—
  (*a.*) On the viscosity of liquids.
  (*b.*) On surface tension.
  (Papers on these subjects will shortly be published in the *Transactions of the Faraday Society*, London.)

B. *Geology Department.*

(1.) Professor R. Speight :—
  (*a.*) A geological survey of the Malvern Hills, with special attention to their economic possibilities.
  (*b.*) A petrological description of the rocks of Banks Peninsula.

(2.) Mr. P. T. Cox : The geology of Rakaia Gorge.

(3.) Mr. J. F. D. White : The geology of the High Peak area, Malvern Hills.

C. *Biology Department.*

Botanical :—

(1.) Miss M. Fitzgerald : The ecology of the Riccarton Bush.

(2.) Miss M. Morrison : The structure and ecology of a group of xerophytic forms from the Port Hills, near Christchurch.

(3.) Mr. E. W. Bennett, M.Sc. : The ecology of the seashore of Banks Peninsula.

(4.) Miss F. B. Murray, M.A. : The germination and seedling growth of the New Zealand taxads (see Report of State Forest Service, p. 25).

(5.) Miss E. M. Herriott, M.A. : The comparative anatomy of the New Zealand Elaeocarpaceae.

(6.) Mr. C. E. Foweraker, M.A. : The investigation of the taxad rain-forest of Westland (see Report of State Forest Service, p. 24).

In addition to the special researches mentioned, the Canterbury College Mountain Biological Station at Cass (2,000 ft. above sea-level) affords opportunities for continued observations and investigations of the montane and subalpine plants of the district.

Zoological :—

(1.) Mr. E. S. Gourley : Investigations on the parasitic Hymenoptera of New Zealand.

(2.) Mr. B. W. Pearce : The reproduction and development of the fresh-water crayfish of New Zealand (*Paranephrops* spp.).

(3.) Dr. C. Chilton : Determination and distribution of the Crustacea, Isopoda, and Amphipoda collected by recent Antarctic and other expeditions.

D. *Chemistry Department.*

Mr. H. O. Askew, M.Z.: A research into the equilibria existing in concentrated aqueous solution of zinc chloride. This research involves measurements of a recognized physico-chemical nature—*e.g.*, migration values, hydrolysis, partition—which may help towards the elucidation of the problem.

4. UNIVERSITY OF OTAGO.

A. *Department of Geology.*

(1.) Professor Park, Director of the Otago School of Mines:—
- (*a.*) Age and extension of the Kaitangata coalfield (see Mines Department Report, p. 28).
- (*b.*) Relationship between the Triassic and Permo-Carboniferous rocks of Nelson.

(2.) Professor W. N. Benson:—
- (*a.*) Geological structure of New Zealand, especially in relation to neighbouring regions.
- (*b.*) Detailed mapping and petrological investigation of the Dunedin district.

(3.) Mr. R. S. Allan, B.Sc., and Mr. Harold J. Finlay, M.Sc.: Stratigraphy and palaeontology of the Tertiary rocks of New Zealand.

B. *Department of Chemistry.*

The following researches are being carried on under the supervision of Professor J. K. Inglis:—

(1.) Mr. Harold J. Finlay, M.Sc.:—
- (*a.*) Examination of the oil obtained in compressing Pintsch oil-gas (communicated to the New Zealand Institute, December, 1922).
- (*b.*) Essential oil and tannin of the New Zealand pepper-tree (*Drimys colorata*) (communicated to the Australasian Association for the Advancement of Science Congress, January, 1923).
- (*c.*) Recovery of wool-grease from scouring-liquors.

(2.) Mr. F. H. McDowall, M.Sc.:—
- (*a.*) Attempted synthesis of B-methyl-*a*-isopropyl pimelic acid.
- (*b.*) Isomerism of the crotonic and *a*-chlor-crotonic acids (communicated to the Chemical Society, London, 1923).
- (*c.*) Some chemical constituents of the leaves of ngaio (*Myoporum laetum*) (communicated to the Australasian Association for the Advancement of Science Congress, 1923).

(3.) Mr. R. Gardner, B.Sc.: Essential oil of manuka (*Leptospermum scoparium*) (communicated to the Chemical Society, London, 1923).

(4.) Mr. B. H. Goudie, B.Sc.: Essential oils of *Dacrydium biforme* and of *Libocedrus Bidwillii.*

(5.) Mr. G. M. Moir, B.Sc.: Synthesis of substances related to pinic acid.

(6.) Mr. D. C. Stephens, B.Sc.: Preparations of cyanacetic acid (communicated to the Australasian Association for the Advancement of Science Congress, 1923).

(7.) Mr. K. C. Roberts: Quantitative investigations of the preparations of ethyl acetate and acetoacetate.

(NOTE.—The Edmond Research Fellowship, held by Mr. H. J. Finlay, is given for the encouragement of chemical research, upon the natural products of New Zealand, or upon problems arising in connection with the agricultural and horticultural industries.)

C. *Department of Biology.*

(1.) Professor W. B. Benham, F.R.S.: Examination of the Polychaeta gathered by the "Terra Nova" in Captain Scott's last expedition to the Antarctic (entrusted to him by the British Museum authorities).
(2.) Mrs. Winifred Aitken, Lecturer in Botany: Anatomy of the genus *Aciphylla*.
(3.) Miss McCarthy: Structure and life-history of *Astelia nervosa*.
(4.) Mr. E. F. Northcroft: Ecology of Lawyer's Head, near Dunedin.

D. *Medical School.*

(1.) Professor J. Malcolm, Dean of the Faculty of Medicine:—
  (*a.*) Food values of certain New Zealand fishes (N.Z. Institute research).
  (*b.*) Pharmacology of New Zealand plants, with especial reference to tutin and pukateine (N.Z. Institute research).
  (*c.*) Influence of the internal secretions on calcium metabolism.
(2.) Dr. R. R. Milligan:—
  (*a.*) Metabolism of the tuatara (*Sphenodon punctatus*).
  (*b.*) Conditions affecting the heart when chloroform is administered.
(3.) Dr. Muriel Bell: Researches on basal metabolism.
(4.) Dr. J. Cairney: On the tortuosity of the carotid arteries in man, and its relation to operations on the tonsil.
(5.) Dr. Rawnsley: Respiratory changes during convulsions.
(6.) Mr. Denny Brown: On the brain of *Sphenodon*.
(7.) Mr. Eppstein: On non-medullated fibres in the nerves of man, as shown by Ransen's pyridine method.
(8.) Dr. C. S. Hicks and Dr. Lynch: Observations on the chemistry of blood by the newer methods of Folin, Wu, &c., and fractional gastric analyses.
(9.) Professor A. Murray Drennan and Dr. C. S. Hicks: Investigations into the iodine content of goitres in relation to pathological changes.
(10.) Professor Drennan: Disposition of *Taenia echinococcus* in the dog in hydatid disease.
(11.) Professor Drennan and Professor C. E. Hercus: Serological diagnosis in the dog of hydatid disease.
(12.) Professor Hercus: Routine research on the types of tubercle bacilli present in bone, joint, and gland tuberculosis in Otago.
(13.) Professor Hercus and Mr. Bevan Brown: A survey of the blood types present in the natives of the Pacific, with an attempt to locate further types.
(14.) Miss Gladys M. C. Cameron, M.Sc.: Flora of vaginal swabs.

E. *Department of Ethnology.*

Mr. H. D. Skinner, B.A., Lecturer on Ethnology:—
  (*a.*) Culture of moa-hunters.
  (*b.*) Investigations into the culture of the South Island Maoris. (Mr. Skinner's research into the "Material culture of the Morioris" has just recently been published at Honolulu.)

5. Canterbury Agricultural College, Lincoln.

The following researches are being conducted at the College :—

(1.) Dr. F. W. Hilgendorf :—

(*a.*) Application of Johannsen's and Mendel's principles to plant-breeding. The object (which has been fairly successful so far) has been to select strains, or originate varieties by crossing, of wheat and oats more profitable than those formerly used. This research has been going on continuously for twelve years.

(*b.*) Application of statistical methods to the results of the diffuse agricultural experiments conducted for many years.

(*c.*) Observation of artesian wells (see N.Z. Institute Report, p. 6).

(2.) Mr. M. J. Scott, B.A. :—

(*a.*) Investigation of long-period manuring of grasslands.

(*b.*) Extensive weighings of growing animals to find rates of growth.

V. INDEPENDENT WORKERS.

(1.) Mr. Gilbert Archey, M.A. : Examination and determination of the New Zealand Chilopoda.

(2.) Mr. W. G. Howes, F.E.S. : Study of the aquatic fauna of New Zealand streams and lakes in its relation to the food of fishes.

(3.) Mr. G. V. Hudson, F.E.S. : Life-histories of New Zealand insects, and systematic record of New Zealand Lepidoptera.

(4.) Dr. L. Cockayne, F.R.S. :—

(*a.*) Examination of the tussock-lands of New Zealand from the point of view of their improvement in carrying-capacity (in connection with the Department of Agriculture).

(*b.*) An ecological investigation of the *Nothofagus* forests of New Zealand (in connection with the State Forest Service).

(*c.*) An examination of the distribution of the non-endemic element of the New Zealand flora, with the object of showing its bearing on Willis's "age and area theory."

(*d.*) An examination of the various indigenous-induced plant associations and successions of New Zealand.

(*e.*) Hybridism in the New Zealand flora, with especial reference to its occurrence in the genus *Nothofagus*.

(5.) Dr. P. Marshall :—

(*a.*) Reports on the Upper Cretaceous Ammonites and Mollusca of New Zealand.

(*b.*) Examination of the early Tertiary Mollusca of New Zealand.

(*c.*) Examination of a peculiar kind of tinguaite occurring in Otago Harbour.

(6.) Dr. T. Uttley :—

(*a.*) Description of the Tertiary fossil Bryozoa of New Zealand.

(*b.*) Stratigraphy and palaeontology of the east coast of Wellington and southern Hawke's Bay.

(7.) Mr. Johannes C. Andersen :—

(*a.*) The string games played by the Maoris.

(*b.*) Maori music.

(8.) Dr. P. H. Buck :—
  (*a.*) Maori somatology.
  (*b.*) Maori methods of plaiting and weaving.
(9.) Mr. E. K. Lomas : New Zealand Arachnida.
(10.) Mr. M. Crompton Smith : Researches into the action of light in New Zealand on artists' water-colours.

VI. GOVERNMENT DEPARTMENTS.

It will be seen from the following record that a very considerable amount of valuable research work is being carried on by various Government Departments. The names of the specialists engaged have been given in most instances ; also the heads of the Departments. We think, however, that in future reports it would be a distinct encouragement of the individual research workers, as well as a recognition of their work, if the names of all those so engaged were given. The majority of these researches are of vast commercial importance to the country, especially in the promotion of the primary industries.

1. DEPARTMENT OF AGRICULTURE.

(Dr. C. J. REAKES, Director-General.)

The following research projects are being undertaken by this Department :—

Biology Section (Mr. A. H. Cockayne in charge).

(1.) Mr. N. R. Foy :—
  (*a.*) Conditions governing the longevity of grass and other seeds, with special reference to Chewings fescue.
  (*b.*) Standardization of source-indicators of agricultural seeds (in co-operation with the Seed-control Station, Zurich, Switzerland).
  (*c.*) Standardization of methods of seed and analysis (in co-operation with the Royal Seed-control Station, Copenhagen, Denmark).
  (*d.*) Statistical study of seed impurities and germination behaviour of New-Zealand-grown agricultural seeds.
(2.) Mr. A. H. Cockayne :—
  (*e.*) The economics of crop-production in the production of meat, wool, and milk.
  (*f.*) The influence of turnips on the tainting of milk.
  (*g.*) The influence of phosphates on soil-fertility.
  (*h.*) Farm-management methods in the control of root-crop diseases.
(3.) Mr. E. Bruce Levy :—
  (*i.*) The factors influencing succession in New Zealand grasslands. (This represents a large series of connected researches and investigations in applied ecology.)
  (*j.*) The management of low tussock grassland in New Zealand.
  (*k.*) Critical systematic study of succession dominants in grassland association.
(4.) Mr. G. H. Cunningham :—
  (*l.*) Investigations of fungus diseases of forest-trees and sawn timber.
  (*m.*) Fungus diseases of agricultural plants, with special relation to their life-history and control under New Zealand conditions.
  (*n.*) Taxonomy of the Uredinales and Ustilaginales occurring in New Zealand.

(5.) Mr. R. Waters :—
- (*o.*) The relation of soil bacteria on the availability of insoluble phosphates.
- (*p.*) The bee-diseases occurring in New Zealand.
- (*q.*) Fermentation of honey.
- (*r.*) The cause and control of apple-flesh collapse.
- (*s.*) Improved technique in the production of starters for cheese-manufacture.

(6.) Mr. E. H. Atkinson :—
- (*t.*) Chemical and biological factors in the control of woody stemmed weeds.
- (*u.*) Ecology of indigenous and introduced weeds.
- (*v.*) Study of hybridism in the genus *Nothofagus* (in co-operation with Dr. L. Cockayne, F.R.S.).

(7.) Mr. D. Miller, assisted by Mr. J. Myers :—
- (*w.*) Researches on insects, birds, and other animals in New Zealand affecting—
  - (i.) Agricultural crops—*e.g.*, relation of indigenous and introduced birds to agriculture.
  - (ii.) Life-history and control of grass-grub, cutworms, &c.
  - (iii.) Orchard crops—*e.g.*, life-history and control under New Zealand conditions of codlin-moth, pear-midge, tomato-caterpillar, red mite, apple mealy bug, fruit-flies.
  - (iv.) Forestry—*e.g.*, gum-tree scale (*Eriococcus coriaceus*), life-history and control of blue-gum psyllid, blue-gum chalcid, lignivorous Coleoptera, Hymenoptera, and Lepidoptera.
  - (v.) Public health—*e.g.*, distribution, life-history, control, and pathogenicity of New Zealand mosquitoes.
  - (vi.) Domestic animals—*e.g.*, distribution, life-history under New Zealand conditions, and control of cattle-tick (*Haemaphysalis bispinosa*), sheep maggot-flies, bot-flies of sheep and horses.
- (*x.*) Systematic work on New Zealand Diptera.
- (*y.*) Systematic work on New Zealand Hemiptera.
- (*z.*) Systematic work on New Zealand Arachnida.

Chemistry Section (Mr. B. C. Aston, F.I.C., F.N.Z.Inst., in charge).

(1.) Mr. B. C. Aston (in conjunction with Messrs. F. Leighton and R. E. Grimmett) :—
- (*a.*) Investigations to determine the cause and cure of obscure diseases in domestic stock.
- (*b.*) Experiments to determine the mortality in domestic stock when such has probably been caused through poison, frequently leading to the investigation of poisonous plants.
- (*c.*) Investigation of soils which present some abnormality in productive capacity, with a view to determining the cause and remedy.
- (*d.*) Investigation of quick methods for testing dairy-products in store.
- (*e.*) Generally, all work which is done to supply advice on chemical points to the Department's officers, often involving work of a research nature.

(2.) Mr. Aston (in conjunction with Mr. L. D. Foster) :—
(*f.*) Determination of the milling and other qualities of New Zealand wheat to ascertain the best districts for wheat-growing and the best varieties to grow.

Live-stock Division (Mr. A. R. Young, M.R.C.V.S., in charge).

(1.) Mr. A. R. Young, M.R.C.V.S., and Mr. J. Lyons, M.R.C.V.S. :—
(*a.*) Malnutrition in cattle and sheep, various aspects.

(2.) Mr. B. C. Aston, F.I.C., F.N.Z.Inst. :—
(*b.*) Effect of top-dressings to determine influence on feeding-value.

(3.) Mr. A. R. Young, M.R.C.V.S. (in conjunction with field staff) :—
(*c.*) Investigation into the value of testing with tuberculin, especially with a view to determining the method of dealing with a tuberculous animal recently saturated with tuberculin.
(*d.*) Investigations into what is the most effective method for the destruction of rabbits where they exist in large numbers over a wide area.
(*e.*) Investigation into the best breed or cross for export lambs.

(4.) Mr. H. A. Reid, F.R.C.V.S., D.V.H., F.R.S.E. (in conjunction with field staff) :—
(*f.*) Investigation into sterility in cows.
(*g.*) The curative treatment for contagious abortion and mastitis.
(*h.*) Investigation into diseases of poultry.
(*i.*) The causes, signs, treatment, and prevention of intestinal parasitic infestation.

(5.) Mr. F. C. Brown :—
(*j.*) Breeding for increased egg-production, and the maintenance of uniform laying types, based on external characters and observations.
(*k.*) The housing of poultry with a view to securing high egg-yields, and for the maintenance of healthy flocks.
(*l.*) The causes and prevention of mortality in chickens during the process of artificial incubation and rearing.
(*m.*) The construction and methods of operating both heated and fireless brooders.
(*n.*) Feeding for heavy egg-production.
(*o.*) The value of lucerne as a poultry-food.
(*p.*) Influence of certain foods on the colour of egg-content.
(*q.*) The priming of table poultry.

2. STATE FOREST SERVICE.

(Captain L. MACKINTOSH ELLIS, Director.)

The research work of this Department, commenced in 1920, is being carried on by the Director and his staff of field officers, together with collaborators outside the Department, working on special lines. The following subjects are now being investigated :—

A. *Silvical Research.*

(1.) Mr. C. E. Foweraker, M.Sc., of Canterbury College : Ecology of the taxad rain-forest of the west coast of the South Island. The field investigations include life-histories, &c., of the following species : White-pine

(*Podocarpus dacrydioides*), miro (*P. ferrugineus*), matai (*P. spicatus*), totara (*P. Totara*), red-pine (*Dacrydium cupressinum*), silver-pine (*D. Colensoi*), and New Zealand cedar (*Libocedrus Bidwillii*).

(2.) Mr. W. R. McGregor, M.Sc., of Auckland University College: Ecology of the kauri forest of the North Island. Similar investigations are being carried on in regard to kauri (*Agathis australis*), red-pine, totara, matai; celery-top pine (*Phyllocladus trichomanoides*), tawa (*Beilschmiedia Tawa*), and taraire (*B. Taraire*). These researches cover a five-year programme.

(3.) Miss F. B. Murray, M.A., Canterbury: Taxad-seed germination and the growth and establishment of taxad seedlings:—

- (*a.*) Investigation of fruit and seed of silver-pine.
- (*b.*) Stages in germination and establishment of the seedling of silver-pine.
- (*c.*) Comparison of the seedling of silver-pine with that of rimu, with an identification scheme for these two very similar seedlings.
- (*d.*) Preliminary investigation of the seedlings of miro, white-pine, and matai.
- (*e.*) Season of seed-maturity; optimum age of mother trees; percentage of viable seeds; germination period; physical and chemical condition of seed-bed.
- (*f.*) Preliminary investigations on the structure of the fruit and seed of miro, white-pine, and totara.

(4.) Mr. E. W. Bennett, M.Sc., of Canterbury College: Nature and significance of the growth-rings and the volume-increment of wood in the New Zealand taxads.

(5.) Dr. L. Cockayne, F.R.S.: Ecology and natural regeneration of the southern-beech (*Nothofagus*) forests, with further investigations into the hybridization of the species of this genus. This research includes—

- (*a.*) The classification of the various types of *Nothofagus* forest; also their regeneration (i) after natural death, (ii) after milling, (iii) after felling;
- (*b.*) The diseases of the *Nothofagus* trees;
- (*c.*) The value of the land in forest as compared with its value as grazing-land;
- (*d.*) The species of *Nothofagus* as timber-trees;
- (*e.*) The present milling of *Nothofagus* and the uses of the timber;
- (*f.*) The rate of germination of the seeds of the principal members of the forest;
- (*g.*) The rate of growth of the principal members of the forest;
- (*h.*) The effect of increase of light on increase of seedlings;
- (*i.*) The life-histories of the various types of forest;
- (*j.*) The effect of introduced animals and introduced plants on the forest.

B. *Silviculture and Management.*

(1.) Underplanting indigenous forest with exotic trees in plots at Whangamomona (Taranaki) and Mamaku (Rotorua).

(2.) Height, diameter, and volume increment of native trees and forests, and effect of thinnings of varying severity, at Whangamomona and at Rimu (Westland).

(3.) Volume studies on rimu (*Dacrydium cupressinum*) of the Southland and Westland Conservation Regions.

C. *Afforestation.*

Direct sowing, methods of planting, planting waste (pumice) lands, &c.

D. *Reclamation of Sand-dunes.*

Reclamation of sand-dunes on experimental station of 2,000 acres near mouth of the Rangitikei River.

E. *Grazing and Game Studies.*

Researches on effect of deer, opossums, &c., on the forests.

F. *Plant Pathology.*

Forest Entomology :—

Mr. D. Miller, F.E.S., of the Department of Agriculture, is undertaking the following researches :—

(1.) Investigation of the life-histories of scale insects, Coleoptera, &c., attacking species of *Eucalyptus;* with means of prevention.

(2.) Investigation of the timbers attacked by the common borer (*Anobium domesticum*).

Forest Mycology :—

Mr. G. H. Cunningham, of the Department of Agriculture, is investigating the pathogenic fungi which attack growing trees and timber.

G. *Economic Research.*

(1.) Professor H. B. Kirk, of Victoria College, and Mr. W. R. McGregor, of Auckland University College : Examination of microscopic structure of New Zealand timbers.

(2.) Testing of timbers; wood-preservation; wood-pulping; bleeding kauri for resin; distillation of kauri-waste; utilization of bush and mill waste.

Practically the whole of the laboratory and testing work is carried on at the School of Engineering, University College, Auckland, under the direction of Mr. S. E. Lamb, Director of the School, assisted by Mr. E. J. McLaren, Lecturer in Engineering, and Mr. W. R. McGregor, Lecturer in Botany. The work is directed from the central office of the Service, Wellington.

3. GEOLOGICAL SURVEY.

(P. G. MORGAN, M.A., Director.)

The activities of the Geological Survey may be roughly summarized as follows :—

(1.) Areal geological surveys, including a good deal of topographic survey. The following districts are being systematically surveyed at the present time, viz. : (*a*) Kaipara district (Dargaville Subdivision), North Auckland ; (*b*) North Taranaki (Ohura Subdivision) ; (*c*) East Cape to Cape Runaway district (part of Waiapu Subdivision). Up to the end of March, 1923, about 17,300 square miles had been geologically surveyed in detail.

2.) Special examinations of mines and mining districts.

(3.) Palaeontological research by members of the staff, and more especially by outside specialists. The following are engaged on research work at the present time :—

(*a.*) Mr. J. Marwick, Palaeontologist, is studying the Tertiary Mollusca.

(*b.*) Professor H. L. Hawkins, D.Sc., of Reading, England, is working on Tertiary echinoderms.

(*c.*) Mr. Henry Woods, F.R.S., of Cambridge, England, on Tertiary decapods.

(*d.*) Dr. J. Allan Thomson, Director of the Dominion Museum, on Brachiopoda, mainly those of Tertiary age.

(*e.*) Mr. W. R. B. Oliver, Dominion Museum, on examination of Pleistocene fossil leaves (formerly considered Pliocene) from the Ormond district, Gisborne.

(4.) Collection of data relating to minerals, building-stones, and other useful rocks, soils, water-supply, water-power, &c.

(5.) Publication of results, dealing with—(*a*) The geology and mineral resources of areas surveyed in detail; (*b*) palaeontology; (*c*) mineral resources of the country as a whole. (In addition to the bulletins published by the Survey itself, many official reports have appeared in the *New Zealand Journal of Science and Technology*, and papers by members of the staff are published from time to time in the journal mentioned, in the *Transactions of the New Zealand Institute*, and elsewhere).

(6.) Dissemination of information by correspondence.

(7.) Distribution of mineral and geological specimens.

(8.) Maintenance of a geological library.

4. DEPARTMENT OF MINES.

(Mr. A. H. KIMBELL, Under-Secretary.)

Researches are being carried out in—

(1.) The Dominion Laboratory, on occurrences of coal, clay, cinnabar, kauri-gum, and kauri-peat.

(2.) The Otago School of Mines: Professor James Park is engaged on an examination of the age and extent of the Kaitangata coalfield, dealing more particularly with the probable extension of the coal towards the south.

(3.) The Director of the Coromandel School of Mines is endeavouring to determine the value of the silt in the Coromandel Harbour as a natural fertilizer; also conducting a research on the dressing of flax; and, lastly, in wireless telegraphy.

(4.) The Director of the School of Mines at Reefton is investigating the quantity, location, and marketable value of deposits of magnesite, dolomite, and allied magnesium minerals in New Zealand. In his report he states that the "manufacture of artificial marble now being carried on in Thuringia, where there is now an extensive trade in that product, and the uses of magnesite and dolomite in steel-manufacture, and in the manufacture of Sorel cement, indicate that these deposits are of value to the Dominion."

(5.) The Director of the School of Mines at Waihi is engaged on research work as follows :—
(*a.*) Recovery of kauri-gum from " pukau."
(*b.*) Concentration of cinnabar-ore by oil flotation.
(*c.*) Determination of minute quantities of gold and silver in rocks.

5. DEPARTMENT OF INTERNAL AFFAIRS.

(Mr. J. HISLOP, Under-Secretary.)

A. *Dominion Laboratory.*

(Dr. J. S. MACLAURIN, Dominion Analyst.)

Besides the ordinary routine work of the Laboratory, Dr. Maclaurin and his staff are engaged on analyses of coal, clay, cinnabar, kauri-gum, and kauri-peat on behalf of the Department of Mines. The work on coal includes low-temperature distillation, and an examination of the briquetting properties of the residues and of the raw coal.

B. *Dominion Museum.*

(Dr. J. ALLAN THOMSON, Director.)

Besides routine determinations of plants, animals, and natural products the following researches are in progress :—
(1.) Dr. J. Allan Thomson :—
(*a.*) Revision of the Tertiary Brachiopoda of New Zealand.
(*b.*) Examination of the brachiopods collected by Dr. H. Mortensen, Zoological Museum, Copenhagen, Denmark, in Japan, Philippines, Australia, New Zealand, Panama, and British Columbia.
(*c.*) Description of new Brachiopoda for the Australian Museum, Sydney.
(2.) Mr. Elsdon Best : Maori technology and customs.
(3.) Mr. W. R. B. Oliver :—
(*a.*) Examination of Pleistocene fossil leaves from the Ormond district, Gisborne.
(*b.*) Investigation of ecology of marine littoral belt.
(4.) Mr. Harold Hamilton : Description of the birds of the Australian Antarctic Expedition.
(5.) Mr. W. J. Phillipps : Fish problems of the thermal-lakes district, New Zealand.

The Dominion Museum carries on research in Maori ethnography by field expeditions, in which kinematograph, photography, and phonograph records are secured. Besides Mr. J. McDonald, Acting-Director, and Mr. Elsdon Best, the field party generally includes Mr. Johannes C. Andersen and Dr. P. H. Buck.

C. *Hector Observatory.*

(Dr. C. E. ADAMS, Government Astronomer.)

Research work is carried on at the Observatory on the following :—
(*a.*) Reception of long-distance wireless time-signals, particularly from Bordeaux, France.
(*b.*) Difference of longitude between Wellington and Sydney by observations of the Honolulu W/T time-signals.

(*c.*) On longitude, by photographing the moon and stars on the same plate.
(*d.*) On the position of the moon.
(*e.*) Full records of sunspots (assisted by Mr. R. C. Hayes).
(*f.*) Continuing records of earthquakes of the Milne No. 29 and the Milne-Shaw No. 13 seismographs. These records are analysed and the results published, and earthquake regions determined. Reports are also made from non-instrumental observations of earthquakes.

6. Public Works Department.

(Mr. F. W. Furkert, Engineer-in-Chief and Under-Secretary.)

The following investigations are being carried on by officers of the Department :—

(1.) The testing of transformer-oils and of high-tension insulators (the latter work is being done in conjunction with Professor Farr).
(2.) Continuous records are kept of the run-off of certain watersheds, together with evaporation records, so that it is possible to ascertain the ratio which the run-offs of the watersheds bear to the rainfall.
(3.) Investigation of preservatives for keeping off "borers," both marine and terrestrial.
(4.) Investigation of the water-requirement of various soils and crops in Central Otago (this work is being done in conjunction with the Department of Agriculture).

7. Department of Health (Division of Maori Hygiene).

Dr. P. H. Buck, Director of Maori Hygiene, is carrying out the following lines of research at the present time :—

(1.) *Maori Somatology.*—Further anthropometrical measurements are being carried out on the lines discussed with Professors Arthur Keith and Karl Pearson in London in 1919. More detail is being collected on the lines undertaken by the Bayard Dominick Expeditions from the Bishop Museum, Honolulu. The object is to obtain racial averages, to distinguish Maori types, and investigate intertribal differences, with the view of finding out Melanesian and other racial influences. The mixed population is also being studied with the view of finding out the change in physical characteristics caused by miscegenation with the white race.
(2.) *Condition of the Present Population.*—An attempt is being made, with the assistance of the Maori Councils and Village Committees, to determine the number of full-blooded Maoris, the amount of miscegenation, size of families in the full-blooded and intermixtures, proportion of sexes, &c. To be of any exact scientific value the genealogical method is being employed, and special districts being fully investigated.
(3.) *Maori Arts and Crafts.*—The actual technique and types of work done are being studied in weaving, plaiting, basketry, and netting. With the assistance of ethnological expeditions from the Dominion Museum, a large amount of material has been collected, illustrated with diagrams, photographs, and films. By mutual arrangement with other members of the expedition, the technical detail of the above crafts have been entrusted to me.

(4.) *Maori Decorative Art.*—The coloured patterns and designs in plait-work and weaving are also being investigated to carry on the series already commenced with Maori decorative house-panels. The technique and names of the various designs are being recorded, together with the differences existing in the various tribal areas. Diagrams and photographs are being accumulated.

(5.) *The Maori Fishing Complex.*—Considerable detail is being gathered to throw light on this complex, which up to the present is the least investigated of the various Maori complexus.

The following papers have either been already published or are in the press for the *Transactions of the New Zealand Institute*, or the *Polynesian Journal*:—

(1.) "The Maori Food-supplies of Lake Rotorua"; with ancient methods of obtaining them, and full description of nets and traps employed.

(2.) "Maori Decorative Art: Part I, House-panels"; with description of technique, various patterns and designs, and illustrated with diagrams and photos.

(3.) "Maori Plaited Basketry and Plaitwork: Part I, Mats, Baskets, and Burden-carriers"; with details of preparation of material, technique, and varieties of articles made. "Part II, Belts and Bands, Fire-fans and Fly-flaps, Sails and Sandals"; with technique and varieties made. Illustrated with diagrams and photographs.

(4.) "The Coming of the Maori." (The Cawthron Lecture for 1922.)

(5.) "The Passing of the Maori": Dealing with population statistics, proportion of sexes, and increasing miscegenation as revealed by the data specially collected from Native schools; absorption as against extinction.

(6.) "Maori Somatology": Racial averages taken from an anthropometrical survey of 424 full-blooded Maoris of the New Zealand Maori Battalion, with tables: (*a*) General characteristics, weight, height; (*b*) sitting height and head-measurements; (*c*) face and nose measurements; (*d*) chest and limb measurements.

(7.) "The Evolution of the Maori Art of Weaving": Technique of the various forms of Maori weaving, with discussion of factors in Polynesia and New Zealand that led to the local origin of Maori weaving in New Zealand from the art of basketry.

8. DEPARTMENT OF LANDS AND SURVEY.

A. *Geodesy.*

The Geodetic Survey of New Zealand, which would at the same time control the existing and future "minor" (tertiary) triangulations, was commenced in 1909. In that year a base-line nine miles in length was measured in the Wairarapa district of the North Island. In subsequent years base-lines were measured at Eltham, Kaingaroa Plains, Matamata, and Waitemata, all in the North Island. In addition, operations were commenced to connect the various base-lines by a gridiron system of triangulation, but shortly after the outbreak of the Great War it was found necessary to temporarily suspend all work of this nature. Recently operations have been resumed on the east coast of the North Island. Permanent signals have been erected over a considerable area of country, and the angular measurements are now in hand.

B. *Tidal Operations.*

In response to a communication received from the Lords Commissioners of the Admiralty, a tidal survey was inaugurated in New Zealand in 1909. Tidal constants for the ports of Wellington and Auckland were deduced from the harmonic analysis of the measured hourly heights of the self-registering tide-gauge records. From the tidal constants thus obtained the times and heights of high and low water were predicted by a graphic method controlled by calculation for the ports of Wellington and Auckland.

In 1918 it was decided to discard the graphic method of prediction, and to forward the tidal constants to England for employment in the tide-predicting machine at the National Physical Laboratory, Teddington, London. One of the results of this change was to increase the number of ports for which harmonic tidal constants could be computed, and predictions for the times and heights of high and low water are now published annually for the following ports: Auckland, Wellington, Lyttelton, Dunedin, Bluff, and Westport.

C. *Magnetic Survey.*

The Magnetic Observatory was established in Christchurch Botanic Gardens in 1901 to serve as base station for the magnetic survey then in progress, and as a base for the magnetic work of various expeditions.

The work of recording magnetic declination, horizontal force, and vertical force by the Adie magnetographs commenced in January, 1902, and since then the records have been continuous, though since 1905 the vertical component of the field has been artificially disturbed.

On account of the large amount of work entailed through the reduction and correction to epoch of the field results for the magnetic survey, it was impossible to publish much in the way of hourly values in the early years of the establishment, but these values for magnetic declination and horizontal force have been regularly published for a number of years with the "Annual Report of Survey Operations of the Department of Lands and Survey" (appendix, "Report of Magnetic Observatory"), and lately the tables of hourly values are published separately in a form suitable for future binding. The report also contains each year a table of mean annual values of the magnetic elements for Christchurch. In addition, mean monthly values of declination, horizontal force, and vertical force are published currently in the *New Zealand Journal of Science and Technology*.

In addition to the observations at Christchurch, a subsidiary station has been of late years established at Amberley, twenty-five miles north of Christchurch, beyond the range of artificial disturbance. A complete set of Eschenhagen magnetographs are in operation there in an above-ground insulated structure which can be easily moved if artificial disturbance ever penetrates there. The idea of a floating substation appears to be the real solution of the troubles of magnetic observations near centres of population.

The facilities at the Observatory for comparison and standardization of magnetic instruments have been availed of by a number of important expeditions. In November, 1915, again in May, 1916, and lastly in November, 1920, the "Carnegie," specially designed magnetic surveying-vessel of the Carnegie Institution, visited Lyttelton, and a careful inter-comparison of standards was effected.

D. *Atmospheric Electrical Observations.*

Consequent upon a resolution of the Australasian Association for the Advancement of Science, the Department of Lands and Survey has procured and installed a recording electrograph at the Observatory. Being non-photographic (ink-recording), this instrument will yield results with less labour than, but equally as good as, those from the photo-electrograph.

E. *Seismological Records.*

A Milne seismograph is in operation at the Magnetic Observatory, the records of which are published in the annual report of the Department.

NATURAL-HISTORY NOTE.

The Occurrence of *Melanchra rhodopleura* in the South Island, by Amy Castle, Entomological Division, Dominion Museum.

Dr. J. Allan Thomson forwarded to the Dominion Museum a specimen of *Melanchra rhodopleura* which he captured at Claremont, Middle Waipara, North Canterbury, on the 25th March, 1923. A few days earlier a badly damaged specimen was taken in the same locality. This moth is rare in the North Island, and this is the first record of its capture in the South Island. *M. pictula*, closely allied, but quite distinct in having a white reniform spot on the forewings and hindwings suffused with pink, is found only in the South Island, having been recorded from Macetown, Nevis, and Lake Coleridge.

CORRESPONDENCE.

The Present Position of the Endemic Birds of New Zealand.

SIR,—On page 69 of this *Journal* (vol. 6, No. 2, August, 1923) I made the statement that not a single representative public collection of the indigenous birds of New Zealand exists in the Dominion. Professor W. B. Benham informs me that the Otago University Museum possesses a collection which is thoroughly representative in that it contains specimens of all the land-birds and most of the sea-birds, and includes, moreover, a "study collection" of skins. I regret that I had not realized the extent of the Dunedin collection.

J. G. MYERS.

DOMINION MUSEUM PUBLICATIONS.

Bulletin No. 1.—Out of print.

Bulletin No. 2.—FISHING AND SEA-FOODS OF THE ANCIENT MAORI. Mythological and historical tales; notes on matters connected with the art of fishing as practised in former times. By A. Hamilton. 1908. 73 pp., 79 half-tone illustrations.

Price, 10s. 6d., post free.

Bulletins Nos. 3 and 4.—Out of print.

Bulletin No. 5.—MAORI STOREHOUSES AND KINDRED STRUCTURES: Houses, Platforms, Racks, and Pits used for storing Food, &c. By Elsdon Best. 1916. 108 pp., 46 illustrations.

Price, 10s. 6d., post free.

Bulletin No. 6.—THE PA MAORI. An account of the fortfied villages of the Maori in pre-European and modern times, illustrating methods of village defence by means of scarps, ramparts, fosses, and stockades. With numerous plans and half-tone illustrations. By Elsdon Best.

To be published shortly.

Bulletin No. 7.—THE MAORI CANOE. A description of various types of canoes as employed by the Maori; with notes on Polynesian vessels. With illustrations. By Elsdon Best.

Awaiting publication.

Bulletin No. 8.—GAMES, EXERCISES, AND PASTIMES OF THE MAORI FOLK, with Notes on their Songs and Musical Instruments. With illustrations. By Elsdon Best.

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The above have been written by Mr. Elsdon Best, F.N.Z.Inst., the well-known authority on Maori life, institutions, and customs.

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A REVIEW OF THE ELASMOBRANCH FISHES OF NEW ZEALAND: No. 1.

By W. J. PHILLIPPS, F.L.S., F.R.G.S.

IN this paper an attempt is made to classify certain families of sharks, and to supply a ready means of identification to the species. In connection with the compilation of this work I have to thank Mr. G. Archey, of the Canterbury Museum, and Mr. L. Griffin, of the Auckland Museum, for information received. Mr. W. R. B. Oliver kindly supplied me with photographs in his possession, while I have to acknowledge my indebtedness to Mr. H. Hamilton for considerable assistance in the photographic work.

Except in isolated instances, a fish may be defined as an aquatic vertebrate which uses gills to assimilate oxygen dissolved in the water. In general there are two main classes of the group Fishes, or Pisces—(1) the Elasmobranchii (which includes all sharks, rays, skates, and elephant-fishes), and (2) the Teleostei (true or bony fishes), many of which are common as food for man. The order Selachii includes that portion of the class Elasmobranchii commonly known to us as sharks.

In appearance and structure a typical shark presents numerous features by which it may be immediately recognized. The body is cylindrical and torpedo-shaped, with a distinct snout anterior to the mouth. The skin is rough, and composed of a primitive exoskeleton of dermal origin. The caudal is here heterocercal, while in the Teleosts it is homocercal. The term " heterocercal " implies the type of caudal fin in which the vertebral column does not cease at its base. On each side, immediately behind the head, are a number of more or less vertical gill-clefts. In all other fishes the gills are protected by a shield or operculum with a free posterior margin giving a common opening to the exterior. The olfactory organs here retain a primitive position as pit-like sacs on the ventral surface of the snout. A spiracle (Eustachian tube) is generally present. This is a vestigial gill-cleft, which at an early stage of embryonic growth differs but little from its fellows.

Internally sharks differ from bony fishes in possessing an intestinal spiral valve and a cone-shaped structure between the ventricle and aorta (conus arteriosus), though these characters appear to be subject to considerable variation in different families. As a rule most parts of the skeleton consist of cartilage, though a certain amount of calcification is sometimes evident, due to the deposition of calcareous salts. This may be particularly noticeable in the vertebral centra which constitute the axial skeleton running the whole length of the body. The pectoral and pelvic fins are each supported by internal cartilaginous structures. The pectoral girdle consists of scapular and coracoid regions, each side being fused together ventrally by fibrous connective tissue, while the pelvic girdle is a bar of cartilage placed transversely across the ventral region of the body, and in the male produced backwards to form a clasper. On the side of the body and head, immediately underneath the skin, is a lateral line system of sense organs. This system of sense organs remains in communication with the exterior by means of short canals.

This key will serve to differentiate the various families of sharks outlined here (*cf.* McCulloch, *Check-list Fish. N.S.W.*, 1921, p. 3) :—

A. Seven gill-slits.
  Fam. HEXANCHIDAE. One dorsal fin placed far back.

AA. Five gill-slits.
  B. Anal fin present ; dorsal spines absent.
    C. Eyes with nictitating membrane.
      D. Functional teeth upright and triangular.
        Fam. CARCHARINIDAE. Head normal.
        Fam. SPHYRNIDAE. Head compressed dorso-ventrally into a lateral wing on each side.
      DD. Teeth pavement-like in oblique rows.
        Fam. MUSTELIDAE.
    CC. Eyes without nictitating membrane.
      E. First dorsal over ventrals.
        Fam. SCYLIORHINIDAE. No nasoral grooves.
      EE. First dorsal more or less in advance of ventrals.
        F. Caudal peduncle without lateral keels.
          Fam. ALOPIIDAE. Tail more than half total length.
        FF. Caudal peduncle with lateral keels.
          Fam. CETORHINIDAE. Gill-slits reach from ventral to dorsal surface.
          Fam. ISURIDAE. Gill-slits reaching to ventral but not to dorsal surface.
  BB. Anal fin absent.
    Fam. SCYMNORHINIDAE.
    Fam. SQUALIDAE.
    Fam. CENTROPHORIDAE.
    Fam. ECHINORHINIDAE.
    } These families, sometimes referred to the suborder Cyclospondyli, will be dealt with in a later paper.

Family HEXANCHIDAE.

The sharks of the family Hexanchidae may be readily distinguished from all others in that they have 6–7 gill-clefts and 1 dorsal fin. In most sharks the number of gill-clefts does not exceed 5. Two genera are known from Australia, *Heptranchias* and *Notorhynchus*, which differ only slightly. The latter genus, *Notorhynchus*, is represented in New Zealand. It may be identified by the presence of a single median tooth in the upper jaw, which is absent in *Heptranchias*. Only one species of each of the above genera is known from the South Pacific.

Notorhynchus pectorosus.

The 7-gilled shark is a viviparous species of the open ocean, and is rarely taken. Under the name *Notidanus indicus* this species was listed by Hutton (*Cat. Fish. N.Z.*, p. 79, 1872), founded on a pair of jaws in the Dominion Museum. The Hon. G. M. Thomson (*History Portobello Fish-hatchery*, p. 68, 1921) records a specimen in the Otago University Museum.

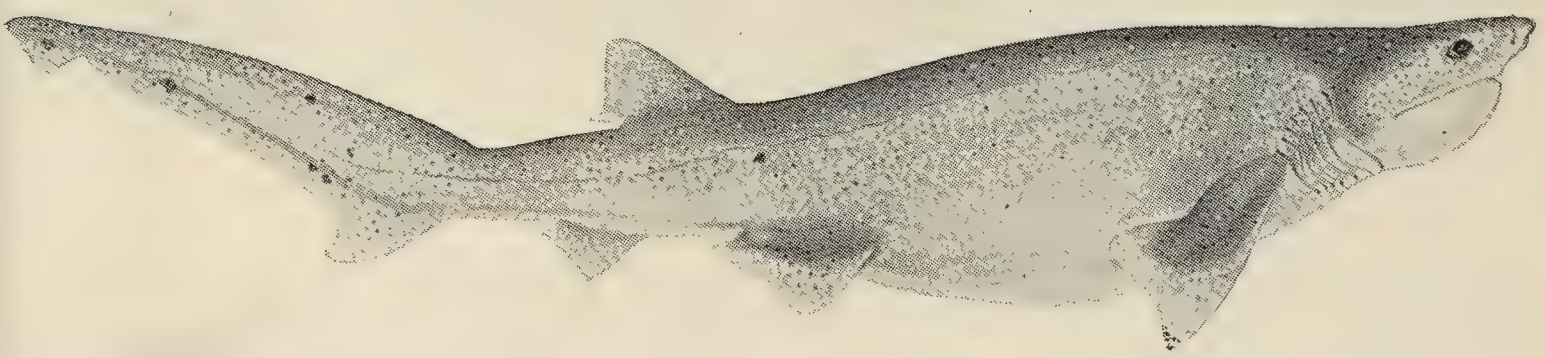

FIG. 1.—Seven-gilled shark, *Notorhynchus pectorosus*. (After Clarke.)*

Clarke's drawing is of a specimen 7 ft. 8 in. long, caught off Hokitika, 3rd May, 1877. The iris of the eye is light brown, the back fins and sides are dark purple, and the lower surface white. Except on the ventral surface the whole of the body and the fins are spotted with numerous dark irregular spots. Interspersed among these spots are a number of larger white and almost circular spots. These are for the most part confined to the dorsal surface, and, though evenly distributed, appear to be irregularly placed. The structure of the skull and visceral arches affords evidence that the 6–7-gilled sharks are the most primitive group of selacians. Fossils have been taken in rocks of the Jurassic age in New Zealand.

Family CARCHARINIDAE.

The sharks of the family Carcharinidae are amongst those separated from others in that a third eyelid or nictating membrane is present. The teeth in both jaws are strongly serrated, those in the upper jaw being generally broad and sloping, and those in the lower more narrow and erect.

The following will supply a ready means of distinguishing the three New Zealand genera :—

Galeorhinus : Spiracles present.

Carcharinus : Spiracles absent ; height of first dorsal is contained less than seven times in length of body to caudal peduncle.

Prionace : Spiracles absent ; height of first dorsal is contained over seven times in length to caudal peduncle.

Galeorhinus australis.

Synonyms : *Galeus canis* (in part) ; *Galeus australis ; Mustelus australis ; Eugaleus australis.*

The southern tope, or school shark, *Galeorhinus australis*, is one of the small so-called dogfish commonly taken by trawlers around New Zealand. The nictating-membrane is here a transversely moving eyelid rising from the inner corner over about two-thirds of the eyeball. The second dorsal rises generally slightly in advance of the anal, which it approximates in size. The height of the first dorsal is contained nearly eight times in the

* All figures of the late F. E. Clarke are published here for the first time.

length of body exclusive of the caudal. Distance from origin of ventral to posterior margin of anal equals distance from snout to origin of pectoral, and is almost equal to length of upper lobe of caudal.

FIG. 2.—Southern tope, *Galeorhinus australis*. (After Clarke.)

The above drawing is of a fish 5½ ft. in length. This is 1 ft. longer than the average. This species bears considerable resemblance to the tope of the Atlantic, *Galeus canis*, commonly taken on the English coasts. The pectoral fin of the southern tope is, however, much longer, broader, and more falcate. A further difference is that in *Galeorhinus australis* the two hinder gill-openings are behind the anterior margin of the pectoral. The colour of the southern tope varies from slaty-purple or bluish-grey to brown, being lighter underneath. Sometimes the ventral surface is almost white. Fins are dark, particularly in the young. As with all Carcharinidae, the species is viviparous, and as many as thirty-four young have been taken from a single female.

Two species of *Carcharinus* are known from New Zealand. I propose to distinguish them as follows :—

Apex of first dorsal obtuse or rounded ; upper caudal lobe two and a half or nearly two and a half times lower caudal lobe .. *lamia.*

Apex of first dorsal acute or pointed ; upper caudal lobe twice lower caudal lobe .. .. *brachyurus.*

Carcharinus lamia.

Origin of dorsal immediately behind base of pectoral, its posterior margin being deeply concave. Second dorsal slightly larger than anal and placed a little farther forward. Upper teeth not conspicuously oblique, serrated with a notch on the posterior margin. Lower teeth finely serrated on both margins.

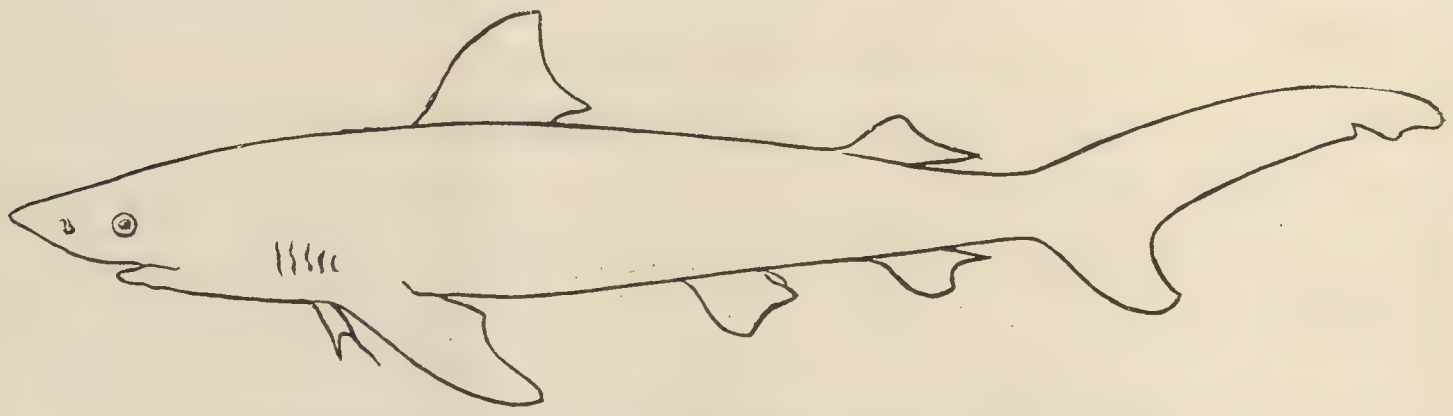

FIG. 3.—Round-finned whaler, *Carcharinus lamia.*

This species is the "lamia," or "requin," of the early writers. It is found in the Pacific in small numbers, being most probably identical with

the fish recorded as *Carcharinus macrurus* (Rams. & Ogil., *P.L.S. N.S.W.* (2), ii, 1888, p. 163). It also does not appear to vary in any marked degree from the species identified as *Carcharinus brachyurus* by Waite (*Rec. Aust. Mus.*, vi, 1906, pp. 226, pl. 39), even though, as Mr. Archey has pointed out to me, from the description given by Gunther (*Cat. Fish. B.M.*, 8, 1870, p. 372) we should call it a short-snouted form. The first notice of the appearance of this fish in New Zealand seas was made by Gunther (*Chall. Rept., Zool.*, 31, 1889, p. 5). It grows to a length of 10 ft., and is common in the tropical parts of the Atlantic and abundant in the Mediterranean and Carribean Seas. Jordan and Evermann describe the lamia as a greedy scavenger about the wharves, and a notorious man-eating shark in tropical seas.

Carcharinus brachyurus.

The type of *Carcharinus brachyurus* was taken in New Zealand seas and described by Gunther (*Cat. Fish. B.M.*, 8, 1870, p. 369). Waite has included the species in his recent work on the fishes of South Australia (*Rec. South Aust. Mus.*, 2, No. 1, 1921, p. 12, fig. 8), where an excellent figure is given, which is here reproduced.

FIG. 4.—The sharp-finned whaler, *Carcharinus brachyurus*.

Recently I had the opportunity of examining two large specimens of *Carcharinus brachyurus* in the Auckland Museum. Dorsal rises a short distance behind base of pectoral, its posterior margin being concave but not deeply so. Second dorsal opposite anal and slightly smaller. Nostrils much nearer mouth than end of snout; first gill-cleft to eye greater than snout to eye, or 1·43 in height of dorsal. Secondary lobe of upper caudal lobe is contained about three and a half times in its length. Width of pectoral is less than twice the length.

I have several photographs of this species, which appears to be common around the North Island.

Prionace glauca.

This species has not been previously recorded from New Zealand. Specimens from New Zealand waters are in the Dominion and Canterbury Museums. The point of origin of the first dorsal may not always be constant; but it may be stated that this point is either midway between the origin of pectoral and ventral or (sometimes) slightly posterior to this point. The slender body and snout and the long falciform pectoral fin mark this species off as quite distinct. Altogether the appearance gives the idea of

general adaptation of structure to speed and dexterity of movement. The species is widely distributed, and may attain a length of 25 ft. This fish is the true blue shark of the Atlantic.

FIG. 5.—Blue shark, *Prionace glauca.* (Dominion Museum specimen.)

The following is a description of the Dominion Museum specimen from Lyall Bay : The length of the pectoral is nearly equal to the distance from its origin forwards to the snout. The origin of the first dorsal is nearer to the origin of the ventrals than to the origin of the pectorals. The second dorsal rises slightly posterior to the anal, which it approximates in size. Lobes of caudal are long and tapering, the upper lobe being contained a little over four times and the lower lobe nine times in the total length of fish. The anterior point of the nostril is exactly half-way between end of snout and mouth, and the greater part of the nostril is nearer the mouth than the snout. The anterior margin of the eye is slightly in front of the mouth. Gill-openings are one and a half times as large as eye.

Family SPHYRNIDAE.

In the sharks of the family Sphyrnidae the head is produced at the sides into dorso-ventrally flattened processes carrying the eyes and nostrils outwards. One genus, *Sphyrna*, is known. Fossil remains have been taken in the Miocene rocks of Europe.

Syhyrna zygaena.

Synonyms : *Squalus zygaena ; Zygaena malleus ; Cestracion zygaena.*

The hammer-headed shark, or mango pare (*Sphyrna zygaena*), appears for the most part to live in the open sea, and is regarded as very dangerous to man. The accompanying figure by Clarke represents a specimen nearly 3 ft. long. It was taken at Paihia, Bay of Islands, September, 1898. The

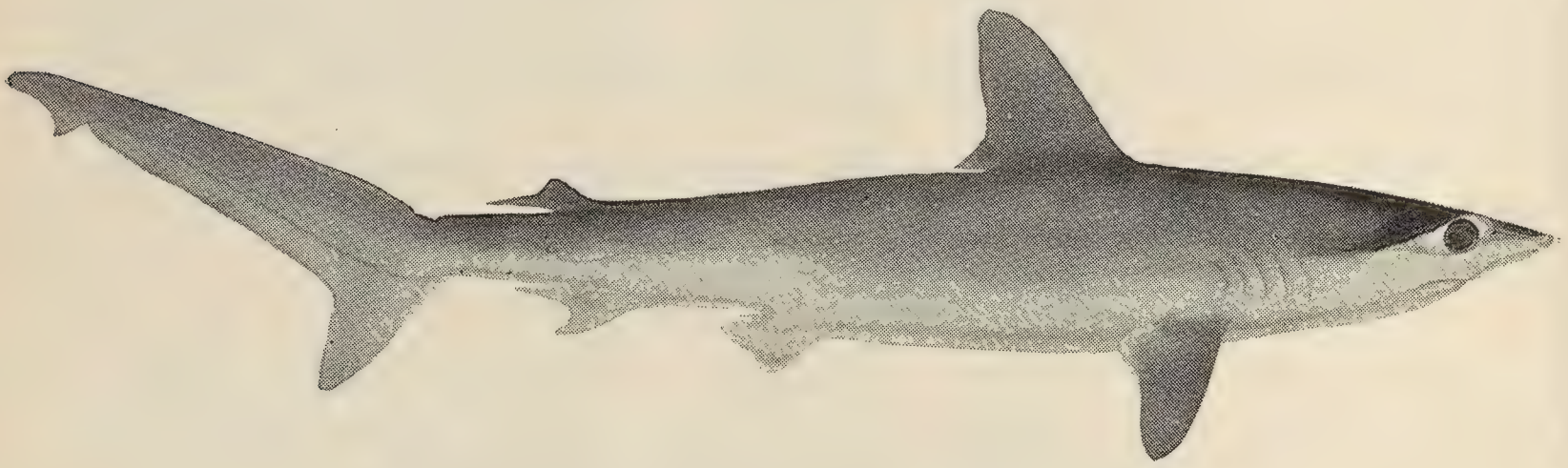

FIG. 6.—Hammer-headed shark, *Sphyrna zygaena.*

top of the head, back, dorsal fins, and caudal fin are of a reddish-purple colour. The pectoral fin is brown, and the ventral and anal whitish tinged with red. Below the colour is white with streaks of reddish tinge. The

average size of specimens taken is generally from 2 ft. to 6 ft., though the full-grown adult is known to be anything up to 15 ft. The Dominion Museum has recently received a small hammer-headed shark, 1 ft. 11 in. long, from the beach at Paraparaumu. The following is a short description :—

The eyes are situated laterally near the anterior corner of each wing of the head. The nostrils are in a small invagination on the anterior margin of the head in front of the eyes. Between the nostrils the front margin of the head is divided into three lobes, one median and two lateral. A pronounced groove runs along the margin of each lateral lobe, and continues ventrally as a faint groove merging into a line to meet the line from the other side just below the point of snout. The second dorsal is

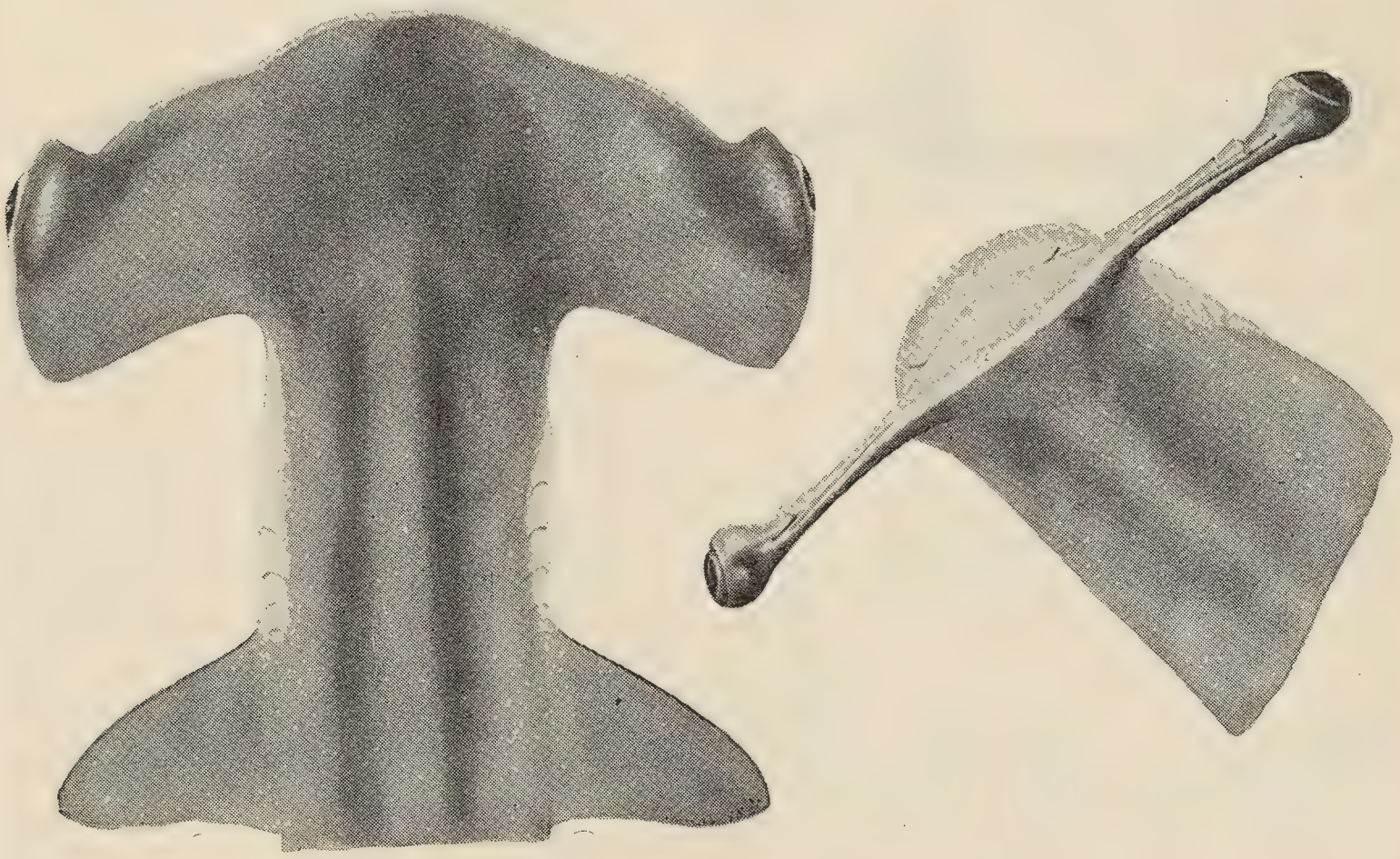

FIG. 6A.—Dorsal and frontal views of head.

situated over the posterior half of the anal and is produced backwards into a long acuminate lobe. The teeth are pyramidal, with smooth edges. In the upper jaw they are somewhat broader than in the lower. There is a middle elongated tooth in each jaw.

Seen laterally the processes of the head appear more or less in the form of a line, as may be ascertained from the side view of the species. The dorsal aspect of the head shows the extent to which the post-orbital and nasal regions of the skull have been modified.

Family MUSTELIDAE.

Mustelus antarcticus.

Synonyms : *Galeus antarcticus* and *Galeorhinus antarcticus*.

The smooth-hound, or gummy (*Mustelus antarcticus*), by which this family is represented, is one of the small sharks commonly taken by trawlers around New Zealand, and popularly termed "dogfish." The family is distinguished by the blunt pavement-like teeth—hence the popular name "gummy," in use in Australia, where the species is also common.

The nearest relative to *Mustelus antarcticus* in the Northern Hemisphere is *Mustelus laevis*, which is not uncommon in the Mediterranean. Some twelve hundred years ago Aristotle placed on record the fact that in the Atlantic species the embryos were developed in the female by the medium of a placenta produced in the uterus. The late Professor T. J. Parker, of the Otago University Museum, was the first to point out that, just as *Mustelus laevis* furnishes a sort of foreshadowing of the true placenta of mammals, so *Mustelus antarcticus* is provided with membranes which, although formed from maternal and not foetal tissues, foreshadow in a remarkable manner the chorion and the amnion.

FIG. 7.—Smooth-hound, *Mustelus antarcticus.*

The above is a drawing by Clarke of a specimen about 2 ft. 4 in. long. The nictitating-membrane is here an extension of the lower eyelid. The first dorsal rises a little behind the pectoral, and the second dorsal is considerably larger than the anal, the origin of which is immediately under the middle of its base. The colour is greyish-blue merging to white below. Back of body and lateral line marked with circular white spots. Mr. W. R. B. Oliver has recorded this species in the Auckland market. This shark was known to the Maoris as "koinga."

Family SCYLIORHINIDAE.

First dorsal rises over the ventral, which fin retains its usual position on the ventral surface. A second dorsal is present. Head and anterior part of the body compressed dorso-ventrally to an extreme degree. Teeth similar in both jaws, being small, with a broad base and three cusps. One genus, represented by a single species, has been taken in New Zealand seas.

Cephaloscyllium sabella.

The carpet-shark, *Cephaloscyllium sabella*, was first listed from New Zealand by Hutton (*Fishes of New Zealand*, p. 80, 1872) under the name of *Scyllium laticeps*. This record was based on a sketch, and afterwards verified when a specimen was taken in Dusky Bay in 1874. A more recent record of the appearance of this species has been made by Waite (*Rec. Cantab. Mus.*, i, p. 136, 1909). Clarke's figure of the species represents a specimen a little over 3 ft. long caught off Hokitika, May, 1877. The colour is brown above, merging to white below. The back and sides are marked with black transverse oblong blotches, which tend to arrange after the manner of the black squares on a draught-board. There are also a number of irregularly placed indefinite black spots on the back and sides.

The following is a description of a specimen 2 ft. 6·8 in. long in the Dominion Museum: The length of eye is contained three times in the distance from the anterior margin of the eye to tip of snout, and is slightly greater than the distance from spiracle to eye. Distance from snout to

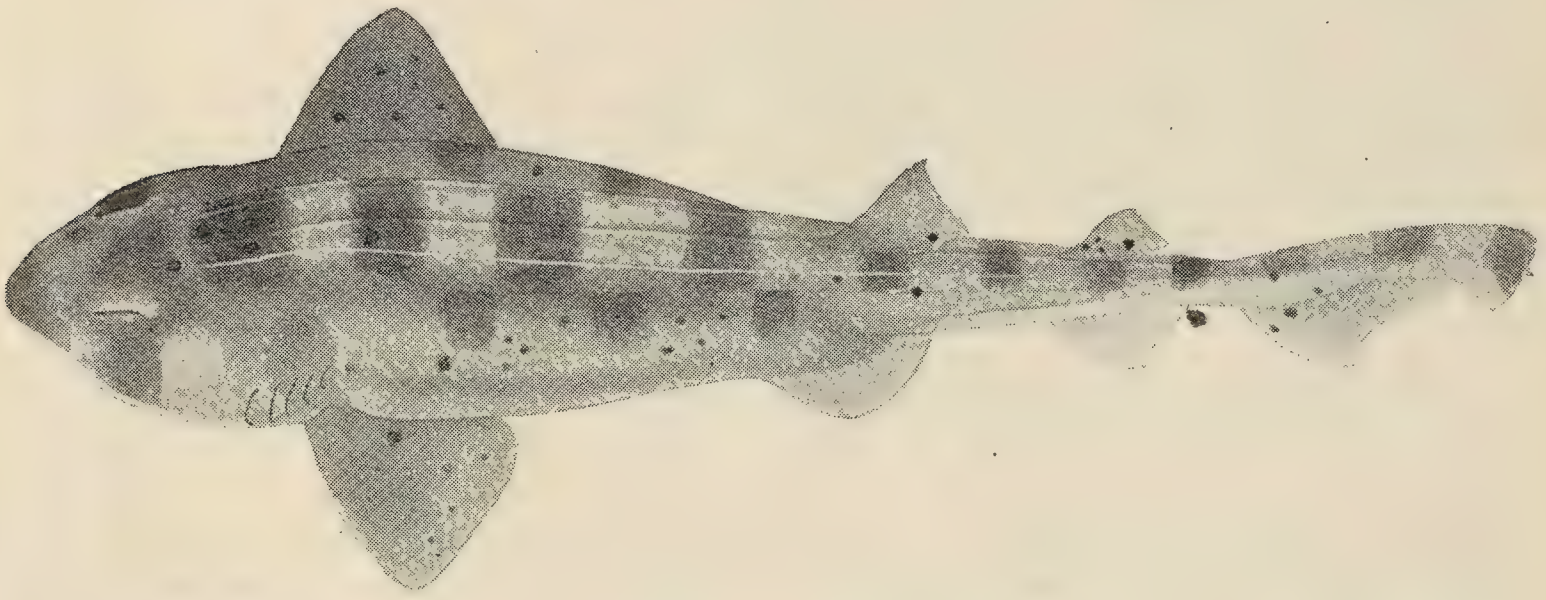

FIG. 8.—Carpet-shark, *Cephaloscyllium sabella*: dorsal view. (After Clarke.)

first gill-opening is contained 6·7 times in total length. Distance from snout to origin of pectoral equals distance from origin of first dorsal to posterior margin of base of second dorsal. First dorsal rises above middle of ventral, and second dorsal slightly posterior to anal. Distance from tip of pectoral on one side to tip of pectoral on the other side measured on the ventral surface is contained just over 2 in length of body. The Dominion Museum specimen agrees in all respects with the accompanying illustration except that the first dorsal fin is more rounded.

Family ALOPIIDAE.

The upper lobe of the caudal is extremely long, making the caudal fin as long as the rest of the body. The ventrals are rather large, and the pectorals very large and falcate. The snout is rather short, the teeth equal in both jaws, flat, triangular, and not serrated. There is a single species, inhabiting the Atlantic and Pacific.

Alopias vulpinus.

Synonyms: *Squalus vulpinus*; *Alopias vulpes*; *Alopecias vulpes*.

The thresher, or sea-fox (*Alopias vulpinus*), was included by Hutton in *Cat. Fish. N.Z.*, p. 78, 1872, on two photographs in the Dominion Museum of a specimen obtained in Blind Bay; but no actual description

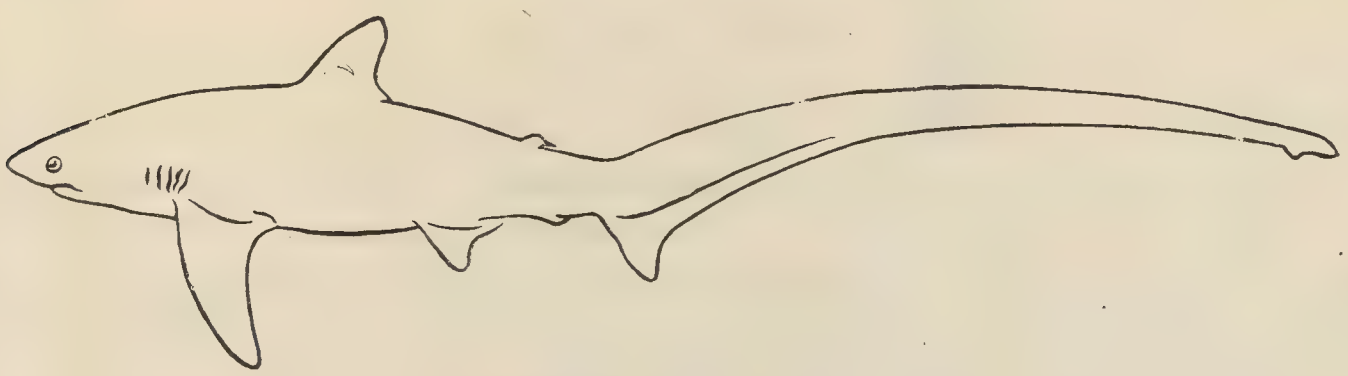

FIG. 9.—Thresher-shark, *Alopias vulpinus*.

of the fish taken on New Zealand coasts exists. There is a specimen in the Auckland Museum, but owing to its position I was unable to make any measurements. The species is abundant in the Atlantic, and has been recorded from each of the Australian States.

The third tooth of the upper jaw on each side is poorly developed. Gill-slits moderate, the last one above the base of the pectoral.

The thresher is inoffensive to man. Its long tail is used to splash the surface water and frighten together the small surface fishes on which it feeds.

Family CETORHINIDAE.

Sharks of immense size, sometimes attaining 40 ft. in length, with the gill-slits extremely wide, reaching from the dorsal surface nearly to the median line of the throat. Teeth small, numerous, and conical, without serrations. A single genus, of which one species is known.

Cetorhinus maximus.

The basking-shark, *Cetorhinus maximus*, is among the largest of living fishes. It is gregarious in its habits, and is known from all oceans in temperate zones. The name has been applied on account of its peculiar habit of lying motionless in the sunshine on the surface. It is not common in New Zealand waters, the first note on its occurrence being made in 1889 (Cheeseman, *Trans. N.Z. Inst.*, vol. 23, p. 126, 1891), when a specimen 34 ft. in length was stranded at Devonport, Auckland.

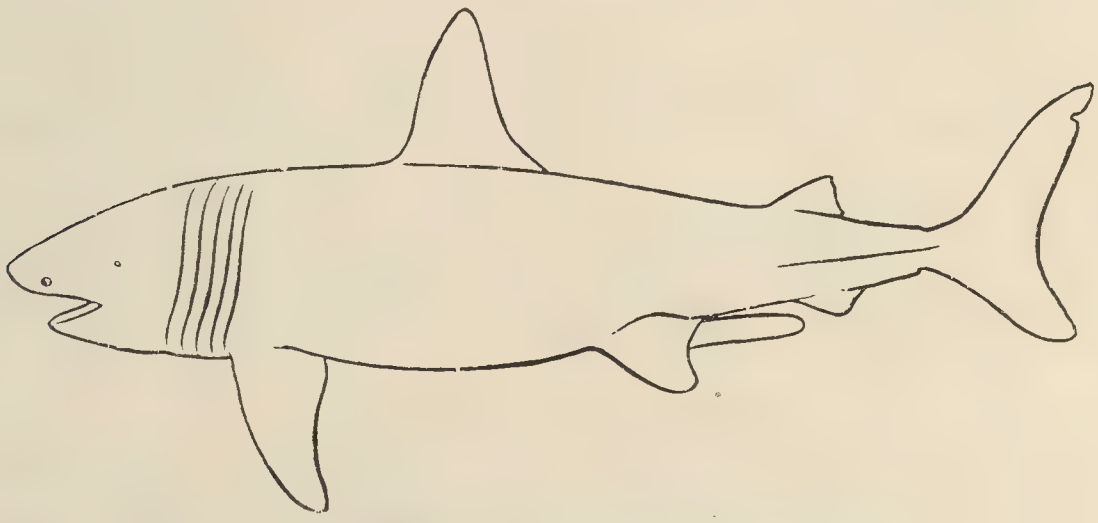

FIG. 10.—Basking-shark, *Cetorhinus maximus*.

The branchial arches are provided on both sides with a comb-like series of gill-rakers, which, though strikingly similar, have quite a different origin to the gill-rakers in the Teleostei. The food consists for the greater part of small types of invertebrates and fishes, which are strained from the water by means of the gill-rakers. There are six or seven rows of teeth in each jaw, with about two hundred in each row. The pectorals are long and the tail large. Fossil remains are not common. Pliocene and possibly some earlier Tertiary deposits are ascribed to this species.

Family ISURIDAE.

The Isuridae are sharks of large size in which the two lobes of the caudal are not very unequal. There is a strong lateral keel on each side of the tail. Pectorals are large and powerful. The muscular system and the dentition are specialized to a considerable degree. There are three genera, all of which are represented on New Zealand coasts. Jordan and Evermann (*Bull. U.S. Nat. Mus.*, 47, pt. i, p. 47) supply the following key:—

A. Teeth slender and sharp, with entire edges.
  B. Teeth without basal cusps, long, flexuous, and acute .. *Isurus.*
  BB. Teeth, or most of them, with a small cusp on each side at base, compressed, sharp, and somewhat triangular .. *Lamna.*
AA. Teeth with serrated edges, compressed and triangular in form, without basal cusp .. .. *Carcharodon.*

It will be seen at once that *Carcharodon* is quite distinct; but the differences between the dentition of *Lamna* and *Isurus* are not as great as may be supposed from the above key. A lower jaw which I take to be *Lamna* is in the Dominion Museum. Only a few teeth near the angle of the mouth and in the innermost rows are supplied with a basal cusp. In fact, it would seem that where the teeth are in a position to be constantly working the basal cusp becomes worn off. The most striking difference which I have found between the teeth of *Isurus* and *Lamna* is that in *Lamna* they are large and upright towards the front, while in *Isurus* they are sharply acute, twisted and long in the same position.

Jordan and Evermann suggest that perhaps *Isurus* and *Lamna* should be united under the older name *Isurus*. Smith (*Journ. Amer. Mus. Nat. Hist.*, 16, p. 342) refers to the porbeagle as *Isurus nasus*. I propose to retain separate generic names, and supply the following as evidence :—

ISURUS.

Origin of dorsal well behind base of pectoral; second dorsal above or slightly in advance of anal. All gill-clefts reaching to ventral surface. Ventral distance from first gill-cleft on one side to first gill-cleft on other side less than ventral distance between the last two pairs of gill-clefts.

LAMNA.

Origin of dorsal above or just behind pectoral; second dorsal above or slightly posterior to anal. Two or three anterior gill-clefts on side of body not reaching to ventral surface. Ventral distance between two anterior gill-clefts greater than ventral distance between two last pairs of gill-clefts.

Lamna nasus.

Synonyms: *Squalus nasus; Squalus cornubicus; Lamna cornubica; Isurus cornubicus; Isurus nasus.*

There is only one published notice of the occurrence of the porbeagle, *Lamna nasus*, on New Zealand coasts, and that is an identification of the

FIG. 11.—Porbeagle shark *Lamna nasus* (young). (After Clarke.)

teeth by Haast (*Trans. N.Z. Inst.*, 7, 1875, p. 237). A lower jaw is among the New Zealand collection in the Dominion Museum. There is also a cast in the Canterbury Museum.* The teeth examined by Haast had basal cusps well developed, and were considered by two Maori carvers then working

*In a *Guide to the Collections in the Otago University Museum*, 1878, p. 35, a specimen of porbeagle is noted. The Hon. G. M. Thomson (*loc. cit.*), states that the species has been occasionally caught in Otago Harbour.

in the Museum to be those of the mako, well known to all Maoris for the excellence of its teeth as articles of adornment. In no instance, however, have I been able to trace basal cusps in entire teeth actually mounted as ornaments, nor do these teeth appear to be as robust as those of the porbeagle. Latterly, by means of inquiry and examination of specimens in the Auckland and Dominion Museums, I have ascertained that the mako is none othen than *Isurus glaucus*, previously unidentified from New Zealand. It is possible, of course, that present-day Maoris would apply the term "mako" to any large shark.

The teeth are long and lanceolate, with sharp lateral edges and usually a basal cusp. At the front there are three teeth on each side, the third tooth being in each case poorly developed. Apart from this frontal and outer row there are four other rows of thirteen teeth each. The colour is dark slaty-grey on the back, merging into black on the edges of the fins; white underneath. The iris of the eye is green.

FIG. 12.—Porbeagle shark, *Lamna nasus* (adult).

Isurus glaucus.

The following is a systematic description of a specimen in the Dominion Museum (locality unknown):—

Snout to first gill-opening equals the distance from origin of ventral to origin of anal, equals half the distance from snout to origin of first dorsal, or five times the pre-oral length. Posterior margin of eye to spiracle is greater than the greatest width of pectoral. Distance posterior margin of base of pectoral to origin of ventral is a little greater than the distance from snout to origin of pectoral. Lower lobe of caudal is contained 1·27 times in upper lobe, which is contained 1·79 times in distance from tip of pectoral on one side to tip of pectoral on other side measured on ventral surface.

The first dorsal rises farther back than shown in the species figured by Waite (*Rec. South Aust. Mus.*, 2, No. 1, p. 21, fig. 27, 1921), and agrees more nearly with that figured by Muller and Henle, copied by Jordan and Evermann in their account of the fishes of Hawaii (*Bull. U.S. Fish. Com.*, 23, pt. i, p. 43, 1903). The second dorsal rises slightly in advance of the anal. The snout has shrivelled to a large extent, and is even relatively shorter than Waite (*loc. cit.*) has figured it.

The teeth are arranged in three to four functional rows. Most teeth are long and flexuous, and point either directly down the throat or towards the roof of the mouth. Those at the sides are more triangular, and those in front narrow. A number of teeth are missing in the specimen; but

those remaining in the upper jaw at the front are sharply oblique and very narrow.

Total length of specimen (male), 4 ft. 3 in. In the female the snout appears to be more acute.

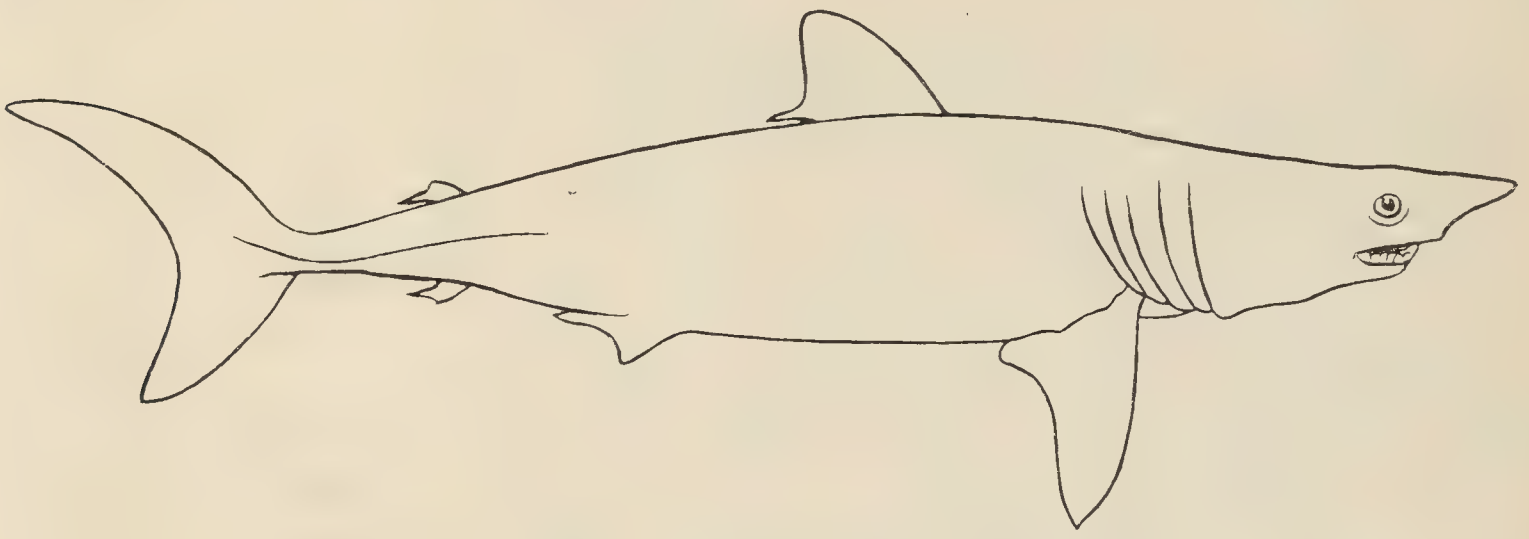

FIG. 13.—Blue pointer, or mako, *Isurus glaucus*.

I have recently had the opportunity of examining a number of photographs of mako taken off Auckland, as well as a male in the Auckland Museum from Manukau bar. All agree with the Dominion Museum specimen described above.

Carcharodon carcharias.

On account of the pure-white colouring of its under-surface, this species is usually referred to as "white pointer" or "white shark." The white shark has been rarely taken on New Zealand coasts, and is probably one of the species which is more at home in the open ocean. It is found in all tropical seas of the world, and is one of the largest and most formidable of all sharks. Like the teeth of the mako, the finely serrated teeth of this species were highly prized as ornaments by the Maoris. Enormous numbers of teeth of an allied species, *Carcharodon rondeletii*, now extinct, have been taken in railway-cuttings and excavations in New Zealand, and I have examined numerous small collections. There is a large specimen of white shark in the Otago University Museum in which the first dorsal is placed relatively farther back than in the figure here reproduced.

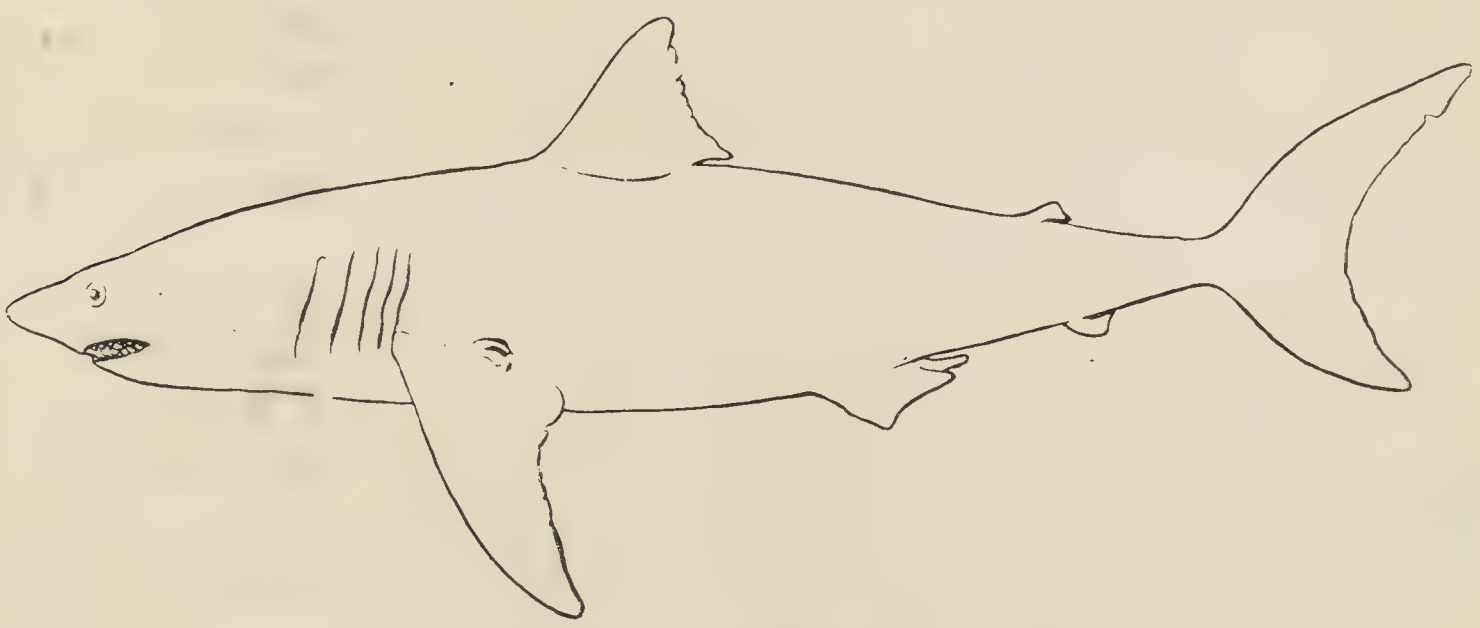

FIG. 14.—White shark, *Carcharodon carcharias*.

The disposition of the fins are practically the same as for the previously mentioned Isuridae. The gill-clefts are large, and placed high up on the side of the body, not reaching to the ventral surface. Ventral distance between first gill-cleft on one side to first gill-cleft on other almost equal to ventral distance between the last two pairs of gill-clefts.

THE STRUCTURE OF THE TAUPO-ROTORUA REGION.

By J. HENDERSON, M.A., D.Sc.

THE Taupo-Rotorua region has attracted the attention of many observers, and the literature dealing with the district is extensive. Its general structure, however, does not seem to have been described, though this, as has been demonstrated by the labours chiefly of Italian geologists, is of the utmost importance in the study of seismology. The more important earthquakes, known as tectonic earthquakes, are due to movements along faults or fractures in the earth's crust. The prime cause of these movements is probably the shrinking of the earth's core through loss of heat, and the adjusting to it of the overlarge, relatively rigid shell. The fold ridges thereby produced form the principal mountain-ranges of the world. The movements do not take place uniformly through a slow continuous warping; but the stresses which tend to produce them are resisted till they have accumulated sufficiently either to rupture the rocks or, if the rocks are already ruptured, to crush unevennesses of the walls of the fracture and overcome the friction between them. Relief is obtained by a series of jolting displacements, which manifest themselves as earthquakes and their after-shocks.

Volcanic action, which is caused by the rising of a mass of molten rock to the surface portion of the earth's shell, is primarily due to the same cause that produces tectonic earthquakes, and is but a manifestation of the action of the same crustal stresses. Volcanic activity, however, also gives rise to a class of earthquakes that have definite characteristics distinguishing them from those of tectonic origin. The remarkable series of earthquakes experienced in the Taupo region during the winter and spring (May to December) of 1922* was undoubtedly tectonic. This is decisively proved by the irregular depression of the land along the northern shores of Lake Taupo in respect to the water-level of the lake and by the long earth-rifts formed across the same area.

R. T. Chamberlain† has recently divided mountain-ranges into (1) a thin-shelled type in which a relatively shallow layer of the earth's crust is affected by the mountain-forming movements, and in which intense folding, overthrusting, and considerable crustal shortening are predominant; and (2) thick-shelled mountains characterized by open gentle folding, by moderate crustal shortening, by strong uplift, and, in many cases, by the extravasation of much lava. Normal faulting along nearly vertical fractures is an important accompanying feature occurring either incidentally or later as a result of the release of pressure.

New Zealand may be regarded as the crest of a broad arch or fold—that is, a "thick-shelled mountain-range." The fold has a north-east course marked by the South Island and by the ranges of Wellington and east Auckland. It is continued as a submarine ridge to Tonga. The

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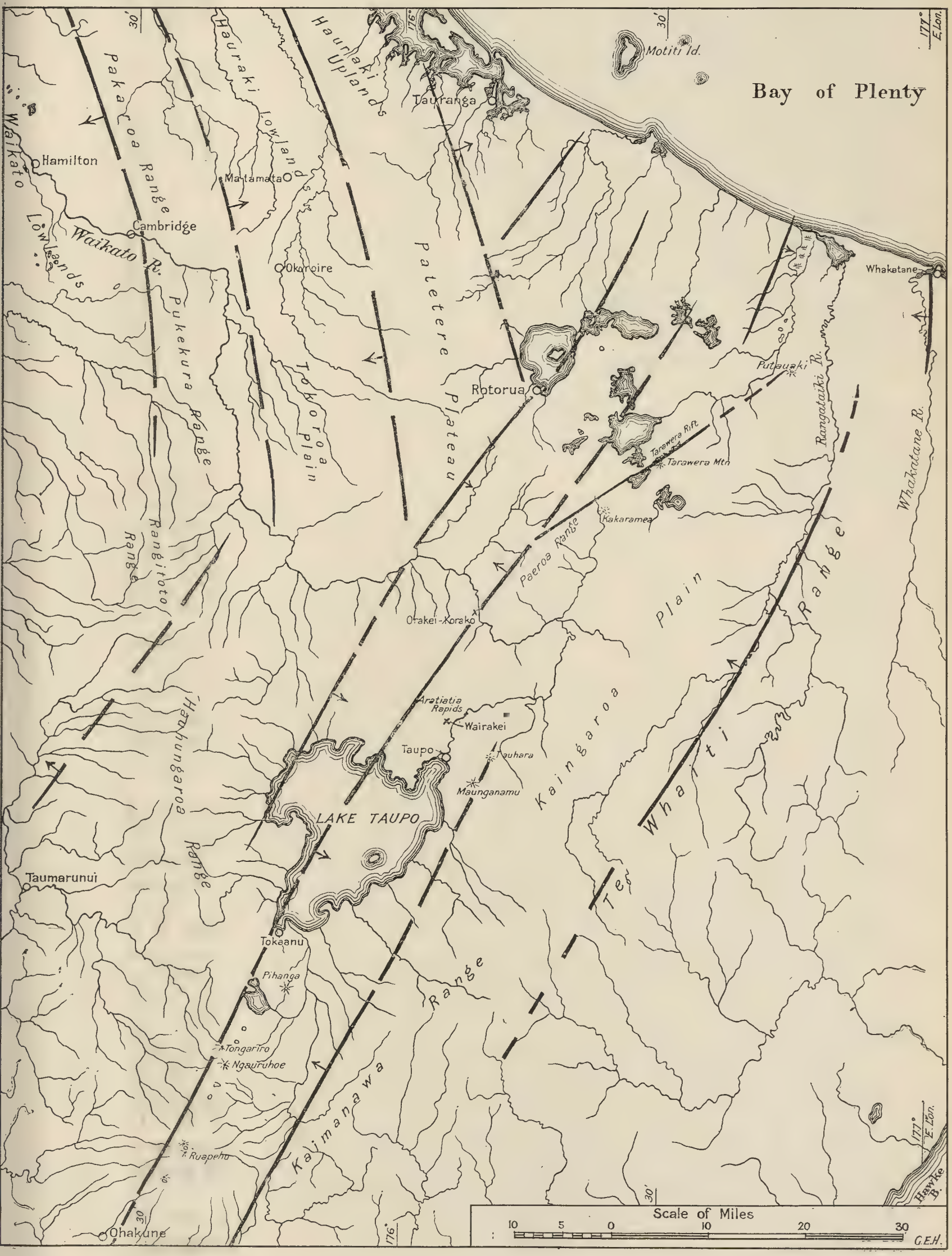
* See P. G. MORGAN, Taupo Earthquakes, *N.Z.G.S. 17th Ann. Rep.*, pp. 10–11, 1923.

† R. T. CHAMBERLAIN, The Building of the Colorado Rockies, *Journal of Geology*, vol. 27, pp. 225–51, 1919; and Vulcanism and Mountain-making, *op. cit.*, vol. 29. pp. 166–72.

North Auckland Peninsula marks a similar but less prominent arch, which meets the principal fold in the Taupo-Rotorua region. The rocks of the crust are in tension along the crest of the arches, so that fractures, more



MAP OF TAUPO-ROTORUA REGION, SHOWING APPROXIMATE POSITION OF FAULT-ZONES.

or less parallel with the direction of folding, and penetrating at right angles to the surface, tend to form. Between these fractures are elongated earth-blocks which, as folding proceeds or when pressure is relaxed, adjust

themselves by differential movements; some blocks maintain their new positions, others settle downwards more or less evenly. A section from Kawhia to Tauranga shows the North Auckland fold in this locality to consist of three elevated plateau-like masses separated by two lowland areas. The elevated blocks are respectively the uplands between the western coast and the Waikato lowlands, the Pakaroa Range separating the Waikato and Hauraki lowlands, and the uplands forming the southern continuation of the Hauraki Peninsula. The western upland here requires no further discussion; the Pakaroa Range continues southward as the Pukekura, Rangitoto, and Hauhungaroa Ranges; and the Hauraki uplands grade southward into the Patetere Plateau.

The great fracture-zone along the western edge of the Hauraki upland has been noted by several geologists and has been definitely traced south beyond Matamata. The nearly straight western edge of the Patetere Plateau forms a prominent physiographic feature and evidently marks its southerly continuation. The mineral springs of Puriri, Te Aroha, Waitearíki, Matamata, and Okoroire occur along this, the Hauraki fault-zone.

The eastern side of the Hauraki-Patetere uplifted block is not so definitely limited as the western, but its steepness and general parallelism with the Hauraki fault strongly suggest the presence of a fracture-zone similar to that feature.

The Hauraki Gulf and the Hauraki Plain (with its southern continuation the Tokoroa Plain) mark the position of a depressed earth-block that in part is covered by thick deposits of pumiceous sands and silts, and in part by the sea. This lowland strip, which is about twelve miles wide, is bounded on the west by the Pakaroa–Pukekura–Rangitoto Range, the base of which has a nearly straight meridional course not quite parallel with the Hauraki fault.

The Taupo-Rotorua region is a depressed area extending some 120 miles or more in a north-easterly direction, for the most part thirty to thirty-five miles wide, but narrower at the southern end where the Ruapehu and Tongariro volcanoes and the Kaimanawa Range occur. Eastward lies a much-dissected elevated region—the Urewera country. Its straight western edge, known as the Te Whaiti Range, suggests that a fracture-zone separates the upland from the lowland area. Bell* seems to have been the first to mention this crustal dislocation. Probably the faults near Whakatane observed by Benson† belong to this zone, which may be termed the Rangitaiki fault.

On its western side, the Taupo-Rotorua depressed area is in contact in part with elevated and in part with foundered blocks. Hochstetter‡ suggested that the steep edge of the Patetere Plateau immediately south of Rotorua was a fault-scarp, and in this he is followed by Thomas.§ This fracture, which is parallel with that bounding the Urewera country, probably continues southward and separates the Hauhungaroa Range from the relatively lower country west of Lake Taupo.

Three great fractures, parallel or nearly parallel with the boundary fault-zones, are known to traverse the Taupo-Rotorua region, and no doubt others occur concealed beneath the vast deposits of fragmental

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* J. M. BELL, *The Wilds of Maoriland*, p. 111, 1914.
† Oral communication from Professor W. N. Benson.
‡ F. VON HOCHSTETTER, *New Zealand*, pp. 400–1, 1867.
§ A. P. W. THOMAS, *Report on the Eruption of Tarawera and Rotomahana, N.Z.*, pp. 13–14, 1888.

volcanic rock. One fracture marked by geysers and innumerable hot springs has been described by Hochstetter* and Thomas.† It passes along the western side of the Paeroa Range through Orakei-Korako, Wairakei, and Tokaanu. Still farther south-westward, occurring on or close to the continuation of this fracture, are the main vents of the Tongariro-Ruapehu group, as well as the small volcanic centre near Ohakune. The earthquake series of 1922 was due to movements along this fracture.

Another great fault-zone, noted long ago by Hector‡ and Park,§ extends along the western base of the Kaimanawa Range. This highland is considered to be the unwarped southern end of the earth-block that northward underlies the eastern half of the Taupo-Rotorua depression. The volcanic cones of Tauhara and Maunganamu rise through the fragmental rhyolitic material concealing this earth-block in direct line with the Kaimanawa fault. The Rangitaiki fault passes along the eastern side of the Kaimanawas and separates these mountains from the Kaweka Range, which forms the southern continuation of the Urewera uplands.

The position of another of the fractures traversing the Taupo-Rotorua region was dramatically disclosed by the eruption of Tarawera in 1886. The series of craters then formed extends along a fissure some nine miles long. The south-westward continuation of the fissure would pass through the important hot springs of Kakaramea and join the Paeroa-Wairakei fracture. If extended north-eastward it would pass close to the well-known volcanic cone of Putauaki (Mount Edgecombe).

In broad outline the geology of the region is simple, though the details of some areas in it must be exceedingly complex. The oldest rocks are greywackes and argillites of Mesozoic age which form the Hauhungaroa, Rangitoto, and Kaimanawa Ranges, as well as the Urewera uplands. The northern end of the Hauraki elevated mass is also formed of these rocks, though the bulk of it consists of andesites, dacites, and rhyolites. The Rotorua-Taupo region is for the most part covered by the youngest of these (rhyolites), which, so far as known, form also the Patetere Plateau. Several types of rhyolite occur. The eruptions were probably long-continued, and are thought to have been connected with the deformative movements that produced the fracture-zones described above. Certainly considerable differential movements of adjacent earth-blocks had taken place before the eruptions ceased, although the older rhyolites were involved in the faulting. The bulk of the material was fragmental, but masses of pasty lava seem to have been forced through fissures, forming puys of no great height, which were no doubt in some cases completely covered by the vast accumulations of fragmental rhyolite from adjacent vents. Mount Tarawera, which was not thought to be a volcano before the 1886 eruption, seems to have been so concealed. The spherulitic rhyolite with vertical fluxion-structure crossed by the Waikato at Aratiatia Rapids is probably the root of a puy.

The last great eruptions of rhyolitic rock seem, as shown by McKay,‖ to have been in the neighbourhood of Taupo. Vast amounts of fragmental material were thrown out; the adjacent mountains were covered with a

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* *Loc. cit.* † *Loc. cit.*

‡ J. HECTOR, Progress Report, *Rep. Geol. Explor. during 1868–69*, No. 5, p. i, 1869.

§ J. PARK, On the Geology of the Western Part of Wellington Provincial District, and Part of Taranaki, *Rep. Geol. Explor.*, No. 18, p. 40, 1887.

‖ A. MCKAY, Report on the Pumicestone Deposits of the Middle Part of th North Island, *Parl. Paper C.–9*, pp. 16–25, 1899.

thick mantle of subaerial tuff, and the depressed areas filled with deposits of tuff and breccia probably in great part reassorted by fluviatile action. Gently-sloping plains were built from Taupo northward to the Bay of Plenty and north-westward to Hauraki Gulf. The Kaiangaroa Plain is a portion of the original surface of these deposits which, over the western half of the Taupo-Rotorua district and in the Hauraki depression, have been much dissected by stream-erosion, the numerous mesas and buttes of these areas being thereby produced.

The andesitic lavas, agglomerates, breccias, and tuffs of Ruapehu, Tongariro, Pihanga, Tauhara, Putauaki, and several other volcanoes are the youngest rocks of the district, these cones having been built after the rhyolitic eruptions had ceased.

From analogy with other parts of the world, earthquakes and volcanic eruptions are more likely to occur in regions where systems of fractures meet, as they do in the Taupo-Rotorua region. Since the days of first European occupation earthquakes have been frequent in the Taupo district. The Rev. James Buller, one of the earliest European visitors, reports that "Shocks of earthquakes are frequently felt at Taupo; but the Natives, little conscious of their cause, have been in the habit of regarding them as tokens of fruitful seasons."* Sir James Hector,† in summarizing the occurrence of earthquakes in New Zealand, gave a census of shocks between 1868 and 1887 that showed the central district of the North Island as the area most subject to earthquakes in New Zealand. But the shocks felt, though numerous, are not severe. Evidently earth-movements are in progress in this region, and the very frequency of the adjustments, manifested on the surface by earthquakes, suggests that stresses are relieved before they accumulate sufficiently to produce earthquakes of the first magnitude.

NEW ZEALAND MINERAL OILS.

By THOMAS H. EASTERFIELD, Cawthron Institute, Nelson, and NORMAN MCCLELLAND, Victoria College, Wellington.

MINERAL oils may be divided into two distinct classes—(1) Petroleum, which occurs as a natural oil, and (2) shale-oil, obtained by the distillation of bituminous shales. As attempts have been made to establish both petroleum and shale-oil industries in New Zealand, the following facts may not be without interest.

PETROLEUM.

Natural oil has been found in a good many places in New Zealand, but only in the neighbourhood of New Plymouth has any considerable flow been obtained. The following table shows the approximate quantities of benzine, kerosene, and wax yielded by oils from different localities. It will be noticed that there is a marked variation in the composition of the oils even from the same locality.

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* JAMES BULLER, in a letter from Kaipara dated 11th February, 1840, *Wesleyan Missionary Notices*, vol. 1 (new series), p. 367, 1842.

† J. HECTOR, On Earthquakes in New Zealand, *Trans. N.Z. Inst.*, vol. 20, p. 451, 1888.

TABLE 1.—COMPOSITION OF SOME NEW ZEALAND PETROLEUMS.

	Locality.				
	New Plymouth (1906).	New Plymouth (1914).	New Plymouth (1890).	Kotuku.	Maruia (Nelson Province).
Specific gravity of crude oil at 15·5° C.	0·84	0·84	0·84	0·886	0·933
Benzine, boiling up to 150° C.	20% S.g. 0·764	6% S.g. 0·787	..	4% S.g. 0·76	2% (approx.)
Kerosene, boiling 150°–300°C.	40% S.g. 0·82	50% S.g. 0·838	70% S.g. 0·82	42% S.g. 0·84	35% S.g. 0·94
Lubricating ? oil, boiling 300°–400° C.	37%	26%	26%	47%	57%
Paraffin-wax	13%	12%	..	Trace	Trace
Residue (pitch)	2%	1·5%	..	5%	6%
Contraction of benzine on sulphonation	..	36%	..	5%	..
Contraction of kerosene on sulphonation	..	30%	15%	32%	..

	Locality.				
	Gisborne.	Whatatutu (near Gisborne).	Waipaoa (near Gisborne).	*Waitangi (near Gisborne).	†Waiotapu (near Rotorua).
Specific gravity of crude oil at 15·5° C.	0·845 (20°)	0·887	0·84	..	0·809
Benzine, boiling up to 150° C.	3% (approx.)	1% (approx.)	..	25% S.g. 0·75	..
Kerosene, boiling 150°–300°C.	39% S.g. 0·83	28% S.g. 0·82	67% S.g. 0·81	42% S.g. 0·83	6%
Lubricating ? oil, boiling 300°–400° C.	52%	67% (300°–445°)	31%	28%	94% (300°–360°)
Paraffin-wax	..	..	..	2%	12%
Residue (pitch)	..	..	..	..	..
Contraction of benzine on sulphonation	..	..	..	..	..
Contraction of kerosene on sulphonation	15%	13%	14%	..	..

* From report by Dr. Maclaurin, Dominion Analyst, 1920, p. 34.
† From report by Dr. Maclaurin, Dominion Analyst, 1922, p. 37.

SHALE-OIL.

There is a large deposit of oil-shale at Orepuki, in Southland, and another at Waikaia, also in the Southland Province. These shales contain no oil, but upon heating to a high temperature the organic matter contained in them is partly decomposed, and a mixture of gas, oil, and wax is produced. The shales from Orepuki and Waikaia are remarkably similar, according to the reports from the Dominion Laboratory. They yield nearly 40 gallons of crude oil per ton of shale, the oil containing 1·5–2 per cent. of sulphur, which is, of course, a disadvantage. The crude oil obtained by a large-scale distillation test was reported on by Boverton Redwood in 1906. It gave—Burning-oil, 25·9 per cent.; gas oil, 3·1 per cent.; medium oil, 4·0 per cent.; lubricating-oil, 17·6 per cent.; hard paraffin,

19·0 per cent.; soft paraffin, 1·1 per cent.: total, 70·7. The difference between the total and 100 is due to the fact that crude oil upon distillation yields a good deal of pitch, coke, and gas.

The Orepuki shale yielded as a by-product ammonia equal to 19 lb. of sulphate of ammonia per ton of shale. At the price of sulphuric acid in New Zealand it does not pay the gas companies to recover ammonia in the form of sulphate.

The New Zealand Coal and Oil Company erected a large oilworks, with twenty continuous Scotch retorts, at Orepuki in 1899, and mined some 14,400 tons of the shale. The company was paid a Government bonus of £5,000 for the first 100,000 gallons of crude oil produced in New Zealand.

The shale-oil industry is of great importance in Scotland, where in 1913 some 3,000,000 tons of shale were distilled. A yield of 30 gallons per ton is considered good in the Scotch industry. In New South Wales there are very large deposits of oil-shale, some beds of which are said to yield 150 gallons of oil to the ton. In Thuringia an oil very similar to shale-oil is produced in large quantity by the destructive distillation of brown coal at comparatively low temperatures.

THE CHEMISTRY OF MINERAL OILS.

All mineral oils are very complex mixtures, and for the sake of those with little knowledge of chemistry the following explanation is given.

Both natural petroleums and shale-oil usually contain a number of oils derived from five distinct series—viz., paraffins, cyclo-paraffins, olefines, benzoles, and naphthalenes.

(*a.*) The paraffins are substances with the general formula C_nH_{2n+2}, the simplest member of the series being marsh-gas, or firedamp, CH_4, a common source of explosion in coal-mines. The first four members of the series are gases at ordinary working-temperatures. Pentane, C_5H_{12}, to nonane, C_9H_{20}, occur in motor-benzine, and are liquids of comparatively low boiling-point. The 10th to the 16th members are found in kerosene, and still higher members in lubricating-oil. From eicosane, $C_{20}H_{42}$, onwards the paraffins are waxy solids with comparatively low melting-points, and they form the chief constituents of commercial paraffin wax. The paraffins are characterized by great chemical stability, being practically unacted-on even by concentrated sulphuric acid. They burn with but little smoke. Pennsylvanian petroleum is said to consist almost entirely of paraffins.

(*b.*) The cycloparaffins, or naphthenes, resemble the paraffins in that they show great chemical stability and burn with little smoke. They have a higher density than the corresponding paraffins, and have the general formula C_nH_{2n}. Cycloparaffins are the chief constituents of the petroleum from Baku (Caucasus).

(*c.*) The olefines, like the cycloparaffins, have the general formula C_nH_{2n}, but differ in that they readily combine with a large number of chemical reagents—*e.g.*, sulphuric acid and chlorine. The oil from Galicia is remarkable for its high olefine content. Shale-oil and low-temperature coal-tar are rich in olefines, but this is not remarkable, since it has been shown by Thorpe and Young that the higher paraffins upon destructive distillation yield a mixture of lower paraffins and olefines. The illuminating-power of coal-gas, burnt in fishtail or batswing burners, is largely due to the olefines present in the gas.

(*d.*) The benzoles have the general formula C_nH_{2n-6}. The first and best known member of the series is benzene (benzol), C_6H_6, a colourless liquid which is present in coal-tar to the extent of about 1 per cent., and from which the whole of the aniline of commerce is prepared. Toluene, or toluol, the second member, is used in the manufacture of tri-nitro-toluol (T.N.T.), the well-known military explosive. The benzoles have a higher density than the olefines, and are more stable. They dissolve in strong sulphuric acid, and burn with a very smoky flame indeed. Burmese petroleum is rich in benzoles, and much of the T.N.T. explosive in the late war was prepared from toluene obtained from this source.

(*e.*) The naphthalenes have much in common with the benzoles. Benzoles and naphthalenes invariably result if the vapours of other oils are passed through a red-hot tube, and it is of historical interest that Faraday discovered benzene whilst investigating the products of compression of the gas resulting from the destructive distillation of whale-oil; it was not isolated from coal-tar until many years later.

Sulphur is present to some extent in nearly all crude mineral oils, and must be eliminated if first-class burning or lubricating oils are to be put on the market. The expense of removing the sulphur may be so great as to render the oil suitable only for oil fuel.

TARANAKI PETROLEUM.

Petroleum has been produced in considerable quantity in the neighbourhood of New Plymouth. In 1906 a very promising flow of oil was obtained from a boring by the Taranaki Oil-wells (Limited), and a modern refinery was erected to handle the oil.

A bonus of £10,000 was received for the first 1,000,000 gallons of crude oil produced, and another bonus of £2,500 for the first 250,000 gallons of refined oil. The best flow was obtained at a depth of about 2,300 ft.; the flow of oil is said to have failed owing to the collapse of the well-casings, and the refinery has been dismantled.

The oil is a semi-solid grease at ordinary temperatures, but liquefies at once at the temperature of the hand. It is practically free from sulphur and from acid and basic constituents. The gravity of the various distillates is higher than that of the oils of similar boiling-point usually found in commerce. The kerosene burns with a smoky flame in an ordinary lamp, and this is found to be due to the presence of hydrocarbons of the benzole series. Toluene is present to the extent of about 10 per cent. in the benzine fraction, and had this fact been known in 1914 there is little doubt that great attention would have been given to the oil by the British Government.

Cycloparaffins are present in very large quantity in the benzine fraction. The benzenoid constituents were removed from the crude distillate boiling below 150° by means of sulphuric acid, and regenerated by diluting the acid and distilling with steam at a temperature above 160°. The regenerated oil was separated by careful fractionation, and yielded benzene, toluene, and the three xylenes in quantity.

The xylenes were identified by conversion to the corresponding phthalic acids. The naphthalenes were separated and identified by means of their characteristic salts with picric acid.

The paraffins in the paraffin wax were separated by a long series of fractional distillations at 6 mm. pressure, the boiling-points lying between 215° and 290° C. A separate experiment showed that the wax could be heated to a higher temperature (350° to 400° C.) for seven days without decomposition.

Table II shows the chemical compounds which the authors have isolated from Taranaki petroleum. Other compounds are undoubtedly present; in particular, the kerosene and lubricating-oil fraction require a more complete examination.

TABLE II.—CHEMICAL COMPOUNDS IDENTIFIED IN NEW PLYMOUTH PETROLEUM.

Paraffins (in the wax).		*Cycloparaffins* (in the benzine and kerosene).	
Tetracosane	$C_{24}H_{50}$.	Methyl cyclopentane	C_6H_{12}.
Pentacosane	$C_{25}H_{52}$.	Cyclohexane	
Hexacosane	$C_{26}H_{54}$.	Methyl cyclohexane	C_7H_{14}.
Octacosane	$C_{28}H_{58}$.	Dimethyl cyclohexane	C_8H_{16}.
Nonacosane	$C_{29}H_{60}$.	*a* Deca naphthene	$C_{10}H_{20}$.
Triacontane	$C_{30}H_{62}$.	Undeca naphthene	$C_{11}H_{22}$.
Hentriacontane	$C_{31}H_{64}$.	Dodeca naphthene	$C_{12}H_{24}$.
Benzoles (in the benzine and kerosene).		*Naphthalenes* (in the kerosene).	
Benzene	C_6H_6.	Naphthalene	$C_{10}H_8$.
Toluene	C_7H_8.	*a* Methyl naphthalene	$C_{11}H_{10}$.
o Xylene		1 : 4 Dimethyl naphthalene	$C_{12}H_{12}$.
m Xylene	C_8H_{10}.	Tetramethyl naphthalene	$C_{14}H_{16}$.
p Xylene			
Mesitylene	C_9H_{12}.		
Pseudocumene			

The expenses of this investigation have been largely borne by a grant from the Government Research Grant Committee of the New Zealand Institute.

The authors wish to express their thanks to Mr. G. Millar, formerly manager of the Taranaki Oil-wells (Limited), for a large quantity of material and much information; to Mr. M. Ongley, New Zealand Geological Survey; Mr. H. Hill; Mr. H. Atmore, M.P., and Hon. Mr. W. W. Snodgrass, M.L.C., for crude oils supplied; also to Mr. P. G. Morgan, Director of the New Zealand Geological Survey, and to Mr. A. H. Kimball, Under-Secretary for Mines, for supplying statistics made use of in this paper.

FURTHER NOTES ON THE TAIERI MORAINE.

By Professor JAMES PARK.

I SPENT the last ten days of November of this year (1923) examining the morainic material as exposed in the ridges lying between Otokaia and the Taieri River. I made the White House Hotel at Henley my headquarters, and may say that my study of this classic moraine was more detailed than any I had previously attempted. My observations supplement, and only to a small extent modify, those already recorded by me in 1910.*

As seen near the main road at Henley and along the bank of the Taieri River the basal material is fairly compact, and mainly composed of water-

* J. PARK, *Trans. N.Z. Inst.*, vol. 42, pp. 589–612.

worn pebbles set in a sandy and gritty matrix, and mingled with a small proportion of angular schist-fragments. In passing upward the angular fragments and blocks of schist become larger and more abundant, and from half-way up the ridge comprise probably 70 per cent. of the deposit.

The slopes of the ridges fronting the main road, and those descending to Manuka Gully, which lies behind the White House Hotel, are wholly occupied by slipped morainic ground. In many places the slips extend from the summit of the ridge to the level of the plain, a vertical height of 400 ft. Irregularly scattered on these slipped slopes at all levels occur numerous angular blocks of mica-schist, some of very large dimensions. Following these blocks to their source, I found they had come from the uppermost part of the deposit near the summit of the ridge.

At a point a quarter of a mile south of the White House Hotel, close to the main road going south, I noticed in 1907 that a morainic .bock of schist was being broken up by blasting. A portion of this block still remains, and measures 10 ft. by 10 ft. by 3 ft. On making inquiry of Mr. Amos McKegg, a settler of long standing in the district, I was informed that most of the morainic boulders that occurred near the road-level between Otokaia and Waihola had been broken up for road-metal and house-foundations in the early "seventies." One large mass that lay on the flat at the foot of the slope half-way between Manuka Gully and the Taieri Bridge produced, he said, 160 loads of road-metal. On the ridges between Titree and Otokaia there are still many transported blocks of schist ranging in weight from 5 to 50 tons. One block of exceptional size weighs approximately 800 tons.

An examination of the morainic material as exposed in the section along the north bank of the Taieri River shows that the country is intersected by a series of faults that run approximately north and south. The position of the faults on the north side of the Taieri is indicated by depressions, and on the south side of the river by similar depressions bounded by well-marked scarp-faced ridges. Where the material shows indications of bedding the disturbance arising from the faults has gently tilted the material in different places towards the north-north-east, north, and north-north-west. The numerous repetitions of the material makes it difficult to estimate even approximately the thickness of the deposit. From what I have seen on this occasion I am inclined to believe that the total thickness does not exceed 500 ft.

As I have elsewhere indicated, the greater part of the deposit is composed of fluvio-glacial drift covered with a veneer of morainic material transported by ice from the mountains on the west side of the Taieri Plain.

The Taieri Plain is a trough bounded on each side by powerful faults. Along the course of these faults on both sides of the plain the quartzose sands and grits of the Lower Tertiary coal-measures have become involved, as may be seen on the eastern shore of Lake Waihola, and near Otokaia.

It is significant that the fluvio-glacial Pleistocene deposits that cover the great western plains of Canada are gravel drifts broadly terraced, and capped by morainic boulders which, as I found (1922) in the headwaters of the Saskatchewan, Deer, and Beaver Rivers, occur singly, or as large and small widely-separated assemblages. The Canadian drifts recall the similar terraced deposits in the Mackenzie country, and at Wanaka, Clyde, Kingston, and Taieri, with their veneer of morainic material.

NOTES ON A MOLLUSCAN COLLECTION OF SUPPOSED WAIAREKAN AGE.

By J. MARWICK, M.A.

ON page 79 of *N.Z. Geological Survey Bulletin No. 8* is a list of twenty-seven species of Mollusca from "Teaneraki (Enfield), Oamaru District. Geol. Surv. loc. 630: Thomas Esdaile, *circa* 1886." This collection is an important one, not only because the locality may be considered as the type of Thomson's "Waiarekan stage" of the Oamaru series, but also because Suter (1917) chose from this collection seven holotypes of new species.

Some of the specimens are certainly intruders. The *Struthiolaria frazeri* is embedded in a large piece of blue-clay matrix identical with that of the Ngaruroro blue clays (Pliocene), the type locality of the species.

Limopsis aurita: Several of the specimens are the small *Limopsis* n. sp., common at Mount Harris, South Canterbury. The preservation, yellow colouring, and all details agree exactly with those of this locality, from which no doubt they came.

The rest of the specimens are probably all from one locality, but it seems unlikely that it is in the Waiareka Valley. The association of species, as well as their preservation and colouring, and the matrix, where preserved, are the same as those of the greensands at McCullough's Bridge, Waihao River.

In a letter dated 15th May, 1920, to Mr. P. G. Morgan, Director of the New Zealand Geological Survey, Mr. T. Esdaile says that he did not collect any fossils from the glauconitic greensands below the tuffs at Teaneraki. His collection from the tuffs is that numbered 831 (Suter, 1921, p. 79), the correctness of which has been identified by the writer from directions given in the letter mentioned.

The index to fossiliferous localities (Hector, 1892, p. 141) gives loc. 630 as from the Mokau River, but in Mr. A. McKay's manuscript book of localities this has been altered to "630A," and "630 Esdaile's collection, Teaneraki, Oamaru, Otago," inserted at some time after the writing of the main manuscript.

This evidence shows that the collection is quite unreliable, and should on no account be used to typify the fauna of the "Waiarekan stage." Probably McKay, when packing up the collections, noticed that two were labelled "630," selected the one he judged to be from Mokau by the matrix, and allocated the other to Esdaile from memory.

Taking into consideration the identity of matrix, preservation, and association of species, it seems best to regard the types of the new species described by Suter as from "greensand, McCullough's Bridge, Waihao River."

LITERATURE.

HECTOR, J., 1892. *Rep. Geol. Explor. No. 21.*
SUTER, H., 1917. *N.Z. Geol. Surv. Pal. Bull. No. 5.*
—— 1921. *N.Z. Geol. Surv. Pal. Bull. No. 8.*

RELATIONSHIP OF THE WAIKATO, WAIPA, AND MOKAU COAL FORMATIONS.

By Professor James Park, Otago University.

Bulletin No. 24 of the New Zealand Geological Survey, by Dr. J. Henderson and Mr. M. Ongley, M.S., deals with the detailed survey of two blocks, one lying to the east and west of the Main Trunk Railway between Otorohanga and the sources of the Waipa River, the other extending from the sea eastwards along the Mokau and Awakino Valleys to Totoro. The surface of these areas is dissected into innumerable ridges and narrow valleys, and for the most part is still covered with dense forest.

In 1885 I examined the Huntly-Raglan* and Waipa-Kawhia† country, and in 1886–87 the western half of the Province of Wellington‡ lying to the west of the Ruahine and Kaimanawa Ranges; also the greater part of the Province of Taranaki and the Mokau-Awakino region along the Auckland-Taranaki boundary. Altogether I made a reconnaissance geological survey of some 7,000 square miles of difficult and at that time inaccessible forest-clad country. In 1885, when examining the Raglan-Waipa-Pirongia country, I worked alone, my base for the most of the time being the Constabulary camp at Hikurangi. In 1886 I was accompanied by a field hand, Charles Williams, who acted as my cook and companion throughout many arduous journeys in the headwaters of the Rangitikei, Wanganui, Waikato, Waipa, Mokau, and Awakino.

Bulletin No. 24 covers part of the ground traversed by me in the Upper Waipa, Mokau, and Awakino areas. It contains a vast array of facts, and in my opinion is a valuable contribution to the geology of a little-known but economically important part of the North Island.

The geological structure is relatively simple. The basement rocks, mainly argillite and greywacke of Middle Mesozoic age, form a dissected platform overspread by a sheet of Middle Tertiary coal-bearing strata. In the upper Waipa and upper Wanganui the denuded surface of the Tertiary strata is covered by a thick sheet of rhyolite and rhyolitic tuffs of late Tertiary date. At Pirongia the Tertiaries are deeply buried beneath piles of andesitic lavas.

In their bulletin Dr. Henderson and Mr. Ongley subdivide the Middle Tertiary strata into three distinct conformable formations or series—namely, the "Te Kuiti series" (which they place at the base of the Tertiaries), the "Mahoenui series," and the "Mokau series"—these three in ascending order.

Reviewing the stratigraphical evidence presented by the authors themselves, we find that their Te Kuiti series rests directly on the basement rocks (p. 26), and contains seams of brown coal. Its uppermost member overlaps on to the Mesozoic rocks. The Mahoenui series, which is

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* *Reports of Geological Explorations*, p. 144, 1885.

† *Ibid*, pp. 138–40.

‡ *Reports of Geological Explorations*, 1886–87, pp. 24–73, 1887; *ibid.*, pp. 167–82, 1887.

supposed to overlie the Te Kuiti series, also rests on the Mesozoic rocks (p. 29), and also contains seams of brown coal.

If the Mahoenui series does overlie the Te Kuiti series as contended by the authors of *Bulletin No. 24*, we can only suppose that the Te Kuiti beds were in part denuded from the basement rocks before the Mahoenui sediments were laid down. This would connote a degree of unconformity that is not supported by the palaeontological evidence. Moreover, the presence of coal-bearing beds in this series would not support the view of simple overlap.

The Mokau series, which is supposedly younger than the Mahoenui series, also contains brown coal, and is reported (p. 32) to rest unconformably on the Te Kuiti series and to overlap on to the Mesozoic rocks. This arrangement supposes that the Mahoenui series was wholly removed, and the Te Kuiti series in part, before the deposition of the Mokau series, all of which postulates a degree of unconformity completely at variance with the palaeontological evidence.

The molluscan life of the Te Kuiti, Mahoenui, and Mokau series is fully set out in *Bulletin No. 24*, and need not be recapitulated here. It is sufficient to say that each of the three series contains many forms that are characteristically Oamaruian.

I agree with Dr. Henderson and Mr. Ongley that for the most part the strata comprising their Te Kuiti, Mahoenui, and Mokau coal-bearing formations rest directly on the platform of Mesozoic rocks; but I still think, as I did in 1885–87, that these three are in the main coeval, and part and parcel of the Oamaruian covering-sheet. To my mind the differences of the sediments in different areas and of the contained life arise from differences of topography along the old Tertiary strands, and of station.

NOTES ON NEW ZEALAND MOLLUSCA.

By A. W. B. POWELL.

I. A REVIEW OF THE RECENT AND FOSSIL NEW ZEALAND SPECIES ASCRIBED TO HIPPONYX.

Gadinia conica Angas, 1867.

Gadinia conica Angas, *P.Z.S.*, pp. 115, 220, pl. 13, f. 27, 1867; *Man. N.Z. Moll.* (H. Suter), p. 1083, 1913. *Gadinia nivea* Hutton, *J. de Conch.*, vol. 26, p. 36, 1878; *Man. N.Z. Moll.* (H. Suter), p. 603, pl. 24, f. 9, 1913. *Amalthea hexagona* Suter, *Trans. N.Z. Inst.*, vol. 38, p. 326, 1906. *Hipponyx hexagonus* Suter, *Man. N.Z. Moll.* (H. Suter), p. 282, pl. 44, f. 1, 1913.

A colony of shells living under a large flat rock at Mount Maunganui, at the entrance to Tauranga Harbour, was discovered about 1905 by E. G. B. Moss, and described by Suter in *Trans. N.Z. Inst.*, vol. 37, as *Hipponyx hexagonus* n. sp. No further specimens have since been reported in either the type locality or any other part of New Zealand, with the

exception of a small colony at South-west Point, Bluff, collected by Captain Bollons, and identified by Suter as his *Hipponyx hexagonus*. This is not altogether surprising, as the opinion of the writer, which is shared by other New Zealand conchologists, is that the *Hipponyx hexagonus* is nothing but an extreme form of *Gadinia conica* Angas. Repeated search by Dr. Bucknill, of Mount Maunganui, Tauranga, failed to locate the *Hipponyx*, although typical specimens of *Gadinia conica* were obtained.

During the month of January, 1923, Dr. Bucknill kindly invited the writer to join him in an exhaustive search for these obscure creatures. The result was gratifying. Four fine large colonies were discovered on the roofs of caverns near low-water mark. In order to make a thorough examination it was necessary to crawl for about 7 ft. or 8 ft. into these caverns, raised only about 18 in. from the floor, and then lie in water, the depth of which varied with the incoming waves. Hundreds of specimens were crowded together on the roofs of these caverns. Those near the edges of the colonies were the flat perfect-shaped *Gadinia*, while those towards the centre, due to crowding, assumed the irregular hexagonal shape mentioned by Suter. The true *Hipponyx* form, however, were not those in direct contact with the rock, but the less fortunate individuals that were unable to find space on the rock and had to take up their abode on the backs of their companions. These shells found it more convenient to grow tall than expand sideways, hence the elevated conoidal form. About two hundred and fifty specimens were gathered, including all stages of growth.

All the specimens examined, including shells from the type locality in the Auckland Museum, identified by Suter as *Hipponyx hexagonus*, show the distinct siphonal groove characteristic of the *Gadinia*. The late Mr. R. Murdoch, of Wanganui, kindly made the necessary examination of the type of *H. hexagonus*, and he had no hesitation in proclaiming it identical with *G. conica*. He also stated that the Chatham Islands specimens, represented by three beach-worn shells, and also the Bluff specimens, were undoubtedly *Gadinia conica*.

Crepidula radiata Hutton, 1873.

> *Pileopsis radiatus* Hutton, *Cat. Tert. Moll.*, p. 14, 1873. *Hipponyx radiatus* Hutton, *P.L.S. N.S.W.* (2), vol. 1, p. 218, 1887; *N.Z. Geol. Surv. Pal. Bull. No. 2*, p. 20, pl. 1, fig. 14, 1914.

The doubtful generic position of this fossil species was first mentioned by Mr. H. J. Finlay, of Dunedin, who suggested that the type in the Geological Survey Department, Wellington, should be re-examined. Mr. J. Marwick kindly made the necessary examination, and his remarks are quoted below :—

"With regard to *Hipponyx radiatus* Hutton, Mr. Finlay's conjecture as to its being a *Crepidula* is, I think, undoubtedly correct. The shell is embedded in a very hard concretionary matrix and so cannot be clearly exposed. I have managed to lay bare the beak, and in addition broke the shell along an old fracture in search of the septum. This, however, must have been smashed before the shell was buried, and its absence probably influenced Hutton's classification. A careful examination of the walls, however, reveals a slight shelf where the septum joined them. The shell is therefore a *Crepidula*. Whether it is synonymous with *Crepidula striata* Hutton is a difficult question to be certain about. Hutton gave as localities for *C. striata*—Awatere (Hochstetter), Broken River, and Oamaru;

but none of his types remain. The Oamaru specimen was probably Awamoan *C. densistria* Suter, and there may have been more than one species represented. Since Zittel's specimen was too poor for description, perhaps the best thing would be to drop *C. striata* altogether as being indeterminable and to use *C. radiata*, since we have the holotype."

Hipponyx antiquatus Linné, *Trans. N.Z. Inst.*, vol. 51, p. 104, 1919.

Recorded fossil from Kawa Creek, west coast, south of Waikato River.

This is now the only remaining authentic *Hipponyx* recorded from New Zealand. A single small and badly worn specimen, measuring only 5 mm. × 4·25 mm. (aperture) × 1 mm. in height, was obtained.

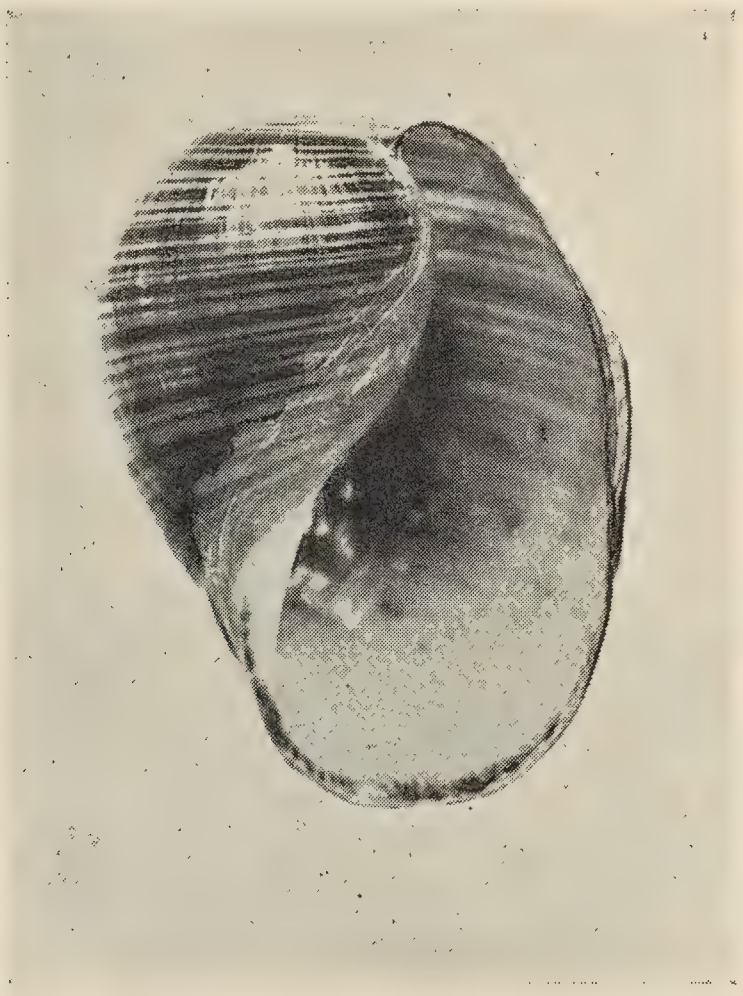
There is no doubt about the generic position of this specimen, but definite specific determination seems out of the question. The concentric lamellar ridges certainly resemble those of the *antiquatus*, but what little radial sculpture there is apparent suggests a much coarser sculpture than that of the true *antiquatus*, which is composed of rather distant striae. The finding of additional specimens in better preservation may prove this shell to be an undescribed species, but for the present it would be better to record only the genus.

II. TWO MARINE SHELLS NEW TO THE NEW ZEALAND FAUNA.

Hydatina physis Linné.

Bulla physis Linné, *Syst. Nat.*, vol. 10, p. 727; Hedley, *P.R.S. N.S.W.*, vol. 51, p. 105, 1917. (For further list of synonomy see *Man. Conch.* (Tryon and Pilsbry), vol. 15, p. 387, 1893.)

A fine large living specimen of this widely distributed shell was discovered at low water on a sandy beach at Tryphena, Great Barrier Island. This interesting find adds a species and also a genus to the New Zealand molluscan fauna.



Hydatina physis Linné. Natural size.

Some idea of the wide distribution of this species can be gained from the following list of localities: Natal (Krauss); Mozambique and Imham-

bane (Peters); Mauritius (Q. & G.); Rodriguez (Robillard); Réunion (Desh.); Seychelles and Amirantes (Dufo); Red Sea (Ehrenb., Cooke); Philippines (Martens); Jeddo, Japan (Lischke); Port Jackson, Botany Bay, and Moreton Bay, Australia (Angas); Sandwich Island (Newcomb); Cuba (Orbigny); Guadeloupe (Beau); St. Thomas (Swift); St. Vincent Island, West Africa (Geisse) (Tryon and Pilsbry, *Man. Conch.*, vol. 15, p. 387, 1893); Norfolk Island (specimen in my collection obtained by the late Mr. C. L. Wragge).

The dimensions of *H. physis* given by Tryon and Pilsbry are 32 mm. × 29 mm., and 29 mm. × 20 mm. The Great Barrier Island specimen is much larger, measuring 49 mm. × 37 mm.

The figure represents the actual specimen which is in the possession of the discoverer, Mr. C. Osborne, who resides at Tryphena, Great Barrier Island.

Recluzia lutea Bennett.

Janthina lutea Bennett, *Narr. Whaling Voy.*, vol. 2, p. 298, 1840.

Still another genus is added to the New Zealand fauna by the finding of a bleached specimen of the above species, measuring 24 mm. × 16 mm., at Tryphena, Great Barrier Island, by Mr. H. Osborne. This interesting addition to our list is now in the possession of Mr. W. La Roche, Auckland.

Distribution.—Australia; Kermadec Islands (Oliver, *Trans. N.Z. Inst.*, vol. 47, p. 525, 1914).

III. NEW LOCALITY RECORDS.

Plaxiphora biramosa Q. & G.

Motutara, west coast, Auckland: three specimens on exposed seaweed-covered rocks at low tide. Mount Maunganui, Bay of Plenty: three specimens were found by Dr. C. E. R. Bucknill. Not previously recorded north of Cook Strait.

Monodonta nigerrima Gmelin.

Found in great numbers at Motutara, west coast, Auckland, but only during March and April of each year. Where they go to for the greater part of the year is quite unaccountable, especially as the other species of the genus occurring at Motutara—namely, *coracina*, *aethiops*, *atrovirens*, *excavata*, and *lugubris*—are always in evidence. This species has not previously been recorded from north of Wellington.

I have in my collection a crimson-coloured specimen which was collected alive from a cluster of several hundreds of the typical form.

Ancilla mucronata Sowerby.

Suter remarks (*Man. N.Z. Moll.*, p. 656) that he had never found this species in the littoral zone. It is interesting, therefore, to record the finding of numbers of living specimens during March, 1923, on a sandspit off Devonport, Auckland. Mr. R. Falla made the discovery; but, although several subsequent trips were made, not a single additional specimen was found.

Austrotriton parkinsonius Perry.

Cymatium parkinsonium Perry, *Man. N.Z. Moll.* (H. Suter), p. 307, 1913.

Two live specimens of this species were found washed up on Taupo Beach, Whangaroa Heads, by Mr. W. La Roche, of Auckland. Hitherto the only New Zealand record was Bay of Islands (J. C. Anderson), a single empty shell.

Cymatium exaratum Reeve.

One live specimen from the net of a local trawler after working in the vicinity of the Hen and Chicken Islands, in 25–30 fathoms. The only previously recorded New Zealand locality was Tauranga, where they are found from time to time washed up on the ocean-beach after storms.

Umbraculum botanicum Hedley.

Umbraculum umbellum Martyn (of Suter's *Man. N.Z. Moll.*, p. 549, 1913). *U. botanicum* Hedley, *P.L.S. N.S.W.*, part 3, p. 315, 1923.

Two live specimens trawled in the vicinity of Hen and Chicken Islands, in 25–30 fathoms. Previously recorded in New Zealand only from Bay of Islands (J. C. Anderson).

Tritonia incerta Bergh, 1904.

Man. N.Z. Moll. (H. Suter), p. 555, 1913.

Described from a single specimen obtained by trawling between Kaipara and New Plymouth (s.s "Doto," 1901). Since then it has been my good fortune to find this species in three localities: (1.) Off Cape Colville, Hauraki Gulf; a number of specimens obtained from the nets of local trawlers from September, 1920, until February, 1921. (2.) Motutara, west coast, Auckland; fifteen specimens noticed during December, 1920, some crawling on stones in shaded rock-pools, others on the sides of a deep rock-pool overshadowed with the large kelp *Durvillea antarctica* at extreme low water. (3.) Mount Maunganui, Bay of Plenty; several specimens noticed during January, 1923, crawling among boulders at low tide on the rocky reef surrounding the beacon near the entrance to Tauranga Harbour.

The colour of this species is brilliant: the dorsal surface and the rhinophores bright orange to vermilion, gills and sides paler, changing to semitransparent grey; foot and buccal veil greyish-white, the lobes of the latter tipped with yellow. Length of average specimen, 130 mm.

In life the dorsal surface is not finely tuberculated as noted by Bergh. This condition develops later, due to contraction in alcohol.

Only one of the specimens examined had the seven lobes in the buccal veil; all the others had more—some as many as twelve and thirteen, but the usual number was nine.

Crassatellites bellulus A. Adams.

One live specimen from nets of local trawler after working in the vicinity of Great Barrier Island, in 30–40 fathoms. Not previously recorded north of Cook Strait.

OCCURRENCE IN SOUTH AMERICA OF THE SHORE ISOPOD *LIGIA NOVAE-ZEALANDIAE* DANA.

By Chas. Chilton, M.A., D.Sc., LL.D., &c., Professor of Biology, Canterbury College, N.Z.

In his report on the Crustacea of the United States Exploring Expedition Dana described a shore isopod, *Ligia novae-zealandiae*, from the Bay of Islands, New Zealand (1852, p. 739), and another species, *L. cursor*, from "Valparaiso ?" (p. 743). In 1879 G. M. Thomson examined specimens from Dunedin, and, finding that they appeared to differ from Dana's description, he considered them to be a different species and named them *L. quadrata* (1879, p. 232). In 1901, in my revision of the terrestrial *Isopoda* of New Zaland, I examined specimens from various parts of New Zealand, including some from Waiwera, north of Auckland, not far from the type locality, and, after comparing them with the descriptions given by Dana and Thomson, came to the conclusion that Thomson's species was the same as Dana's, the differences in the descriptions being due partly to inaccuracies in Dana's description and partly to the fact that the northern specimens were slightly more setose or hairy than those found farther south (1901, p. 107). In 1912 I referred specimens taken at the Kermadec Islands to this same species, pointing out that in one or two characters the Kermadec specimens approached a little more nearly to those found on the Australian coast known as *L. australiensis* Dana (1911, p. 568).

In his account of the terrestrial Isopoda published in 1885 Budde-Lund gave a description (1885, p. 265) of *L. cursor*, based apparently on specimens from Chile, South America, but at the time had, as he imagined, not seen specimens of *L. novae-zealandiae* Dana, merely giving the species as occurring in the Bay of Islands on Dana's authority. In 1922 Mr. H. G. Jackson published a valuable revision of the genus *Ligia*, in the preparation of which he was able to examine Budde-Lund's collection, which is now in the British Museum. He states (1922, p. 697) that he found that Budde-Lund's specimens labelled "*L. cursor*" from Juan Fernandez agreed in every particular but length of antennae with the description I had given (1901, p. 107) of *L. novae-zealandiae;* the Juan Fernandez specimens were all females, and an examination of specimens of *L. novae-zealandiae* named by me showed that the antennae were shorter in the female than in the male and that the females agreed entirely with Budde-Lund's *L. cursor*. Mr. Jackson was also able to examine fragments of a specimen in Budde-Lund's collection named "*L. cursor* (male)" from Chile, and found that the first pair of legs were subchelate like those of the male in *L. novae-zealandiae*. He therefore came to the conclusion that the specimens from Juan Fernandez and Chile named *L. cursor* by Budde-Lund belong to *L. novae-zealandiae* Dana, and that the species therefore occurs in New Zealand, Juan Fernandez, and South America. I have recently been able to examine a female specimen from Valparaiso, sent to me from the Buenos Aires Museum, identified and labelled "*L. cursor* Dana" by Mlle. D. Giambagi, of that museum. On examination I am unable to

distinguish this from female specimens of *L. novae-zealandiae* found on the New Zealand coast, and the conclusion arrived at by Mr. Jackson is therefore confirmed.

Owing to the fact that Dana described the terminal segment of *L. cursor* as "triangulate," and to other differences in his description, Mr. Jackson apparently is of opinion that *L. cursor* Dana may be distinct from *L. novae-zealandiae* (although, as shown above, the specimens named "*L. cursor*" by Budde-Lund are the same as the New Zealand species), and he therefore places *L. cursor* Dana in a list of species "insufficiently described or of doubtful validity." The examination of the Valparaiso specimen sent to me from the Buenos Aires Museum shows that the terminal segment is almost the same as in New Zealand specimens, but is perhaps slightly more triangulate, and I feel little doubt that *L. cursor* Dana is really the same as *L. novae-zealandiae;* the peculiarity that Dana described in the flagellum of the antenna is evidently due to some abnormality, probably to imperfect ecdysis. Assuming that these two species are identical, the name *Ligia novae-zealandiae*, having page precedence, must be retained, although, of course, specimens from South America have to bear it as well as those from New Zealand.

As I pointed out in 1909, these shore and terrestrial Isopoda carry the eggs in brood-pouches under the body until the young are hatched in a form nearly the same as the adult, and it is very unlikely, therefore, that they could cross large tracts of ocean; so that the existence of this shore Isopod in New Zealand, Juan Fernandez, and South America is additional evidence of former land connection between these places (1909, p. 799). Many Crustacea and other animals showing the same distribution are well known, and I need here only add that the shore amphipod *Orchestia chiliensis* M.-Edwards, which lives under almost exactly the same conditions as *Ligia novae-zealandiae*, is also found on the shores of Chile, Juan Fernandez, and New Zealand.

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MAORI STRING-GAMES.

Third Series.

By JOHANNES C. ANDERSEN, F.N.Z.Inst.

With Illustrations by J. McDONALD.

TAHITINUI.

(From Rangi-tahua, a Whanganui man, at Koriniti.)

(Two persons extend the figure.)

1. Opening A.

2. Transfer forefinger loops to ring-fingers, and thumb loops to middle fingers.

3. Place a loop on forefingers as in *takapau* (viz., left thumb into middle-finger loop from below, and draw near string towards you on back of thumb; left forefinger down under thumb string from far side, lift string on back of finger, so that there is a short string between thumb and forefinger. Right forefinger down behind this short string, hook it up and straighten forefinger, turning it from you, in returning to its place; release left thumb).

4. Thumbs under all strings, up behind far little-finger string, and carry this string with them on backs in returning to place.

5. Thumbs into forefinger loops from above, return to place, carrying with them on their backs the far forefinger string.

6. Close other fingers together, and carefully release little fingers. Draw all taut.

7. Little fingers over other strings and into thumb loops from below, return to place, carrying on their backs the far thumb string. Release thumbs.

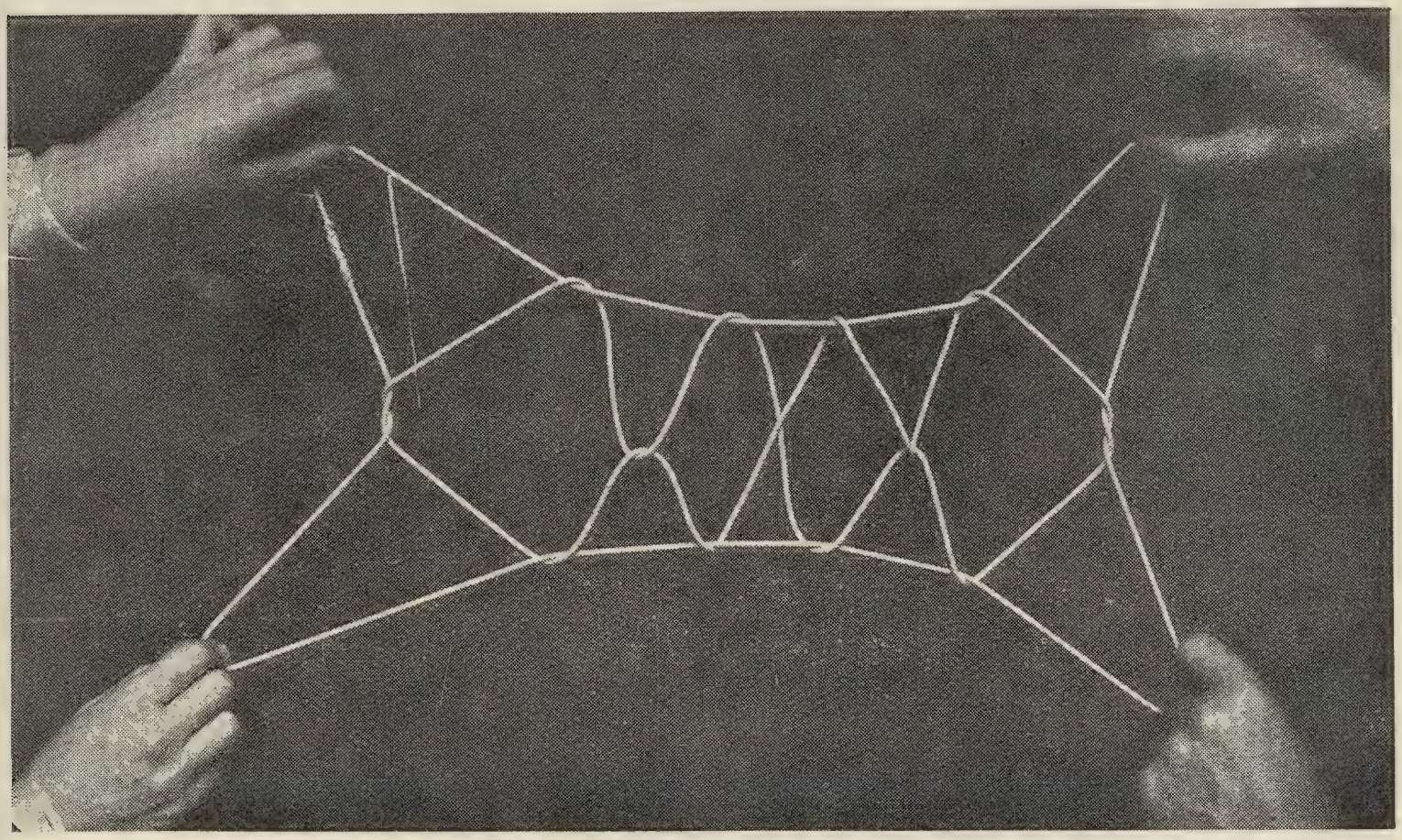

FIG. 1.—Tahitinui.

8. Thumbs over other strings and into little-finger loops from below, return to place, carrying on their backs the near little-finger string.

9. Thumbs into forefinger loops from below, on palmar side of palmar string—that is, they should be inserted under the string close against the forefinger; or the short string between the forefinger and the palmar string

may be lifted over the tip of the thumb by the forefinger and thumb of the other hand.

10. Turn thumbs down through the thumb loop, then up, allowing the near thumb string to slip to palmar side over tips of thumbs.

11. Turn forefingers down into the small triangles through which the thumb loop passes, and whose base is towards the inside of the thumb, its apex being formed of the crossed palmar string and a string going to the centre of the figure. Keeping forefingers down, turn hands till palms are outwards, away from you, fingers pointing upwards, at the same time dropping the loops from the middle, ring, and little fingers.

12. B now takes the loops from A's right (or left) forefinger and thumb, and A takes the loops from his left (or right) forefinger and thumb, untwisting the thumb loop; both separate the hands, and extend the figure between them.

There was something familiar about the figure when it was first seen, and on examining the diamonds, and going over the movements, three things were discovered: the final figure is the same as the Osage diamonds, there is no necessity for the loops on ring and middle fingers, and the figure may be extended by one person; when extended by two, however, it has a finer effect. The figure was obtained on one of the last days of the stay at Koriniti, and the elderly man from whom it was obtained had been practising, as others were, and had perhaps remembered the construction faultily; or it may indeed be that the extra loops are simply used for mystification, as is the involved twisting in the double figure of the house.*

Comparison.

The movements of the Osage diamonds from Pawhuska, Oklahoma, are given for comparison.†

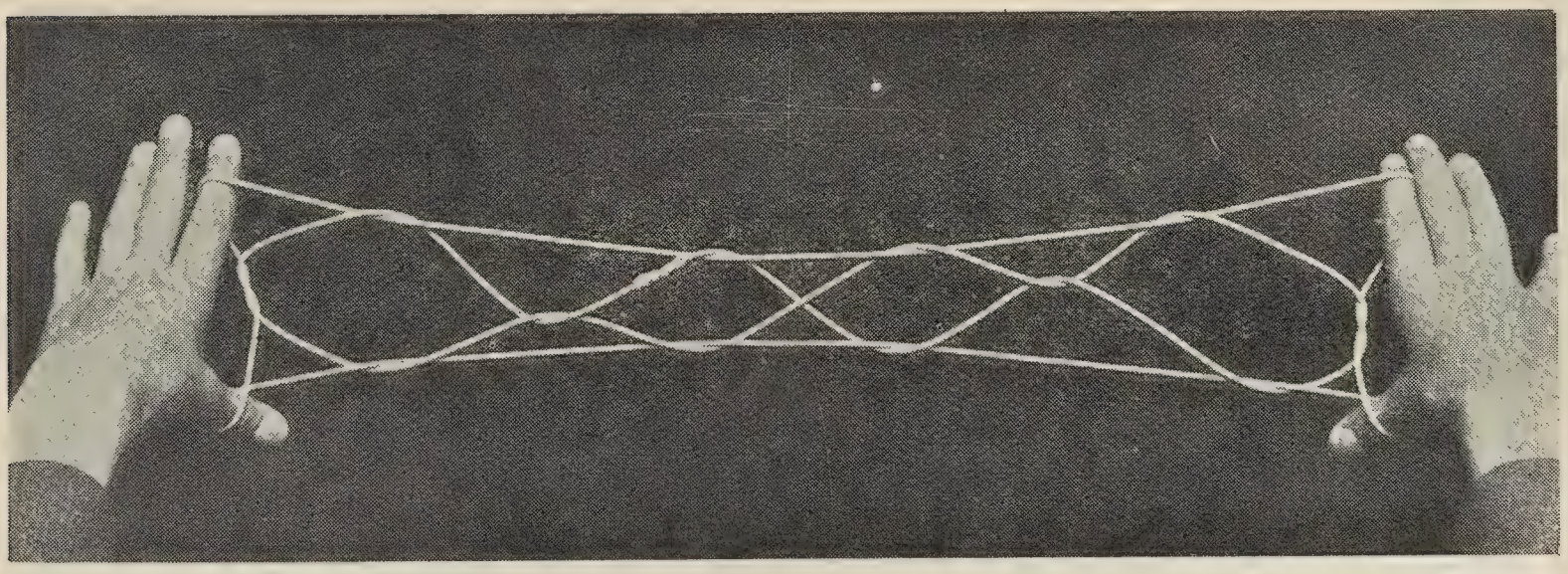

FIG. 2.—Osage diamonds.

1. Opening A.

2. Release thumbs and separate hands, leaving loops on forefingers and little fingers only.

3–10. The same as movements 4–11 of *tahitinui*, except that in the last movement, No. 11, there are no loops to be dropped except from the little fingers.

11. Extend figure between thumbs and forefingers, well spread, the latter upwards.

If the movements are made with three loops on the fingers—on fore, middle, and little fingers—in the final figure the two central diamonds are

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* *N.Z. Jour. Sci. & Tech.*, vol. 3, p. 198, 1920.

† Mrs. Jayne, *loc. cit.*, pp. 24–27.

free, and the figure is the same as an unnamed one learned by Dr. Furness from a native woman, "Emily,"* Caroline Islands. As the construction is entirely different it is given for comparison :—

1. Opening A.

2. Let forefinger loops slip over fingers and backs of hands, down to wrists.

3. Forefingers down into little-finger loop, carry away the near little-finger string on side of forefinger, and insert forefinger from above into thumb loop. Take up far thumb string in returning forefingers to position.

4. Withdraw thumbs from their loops, and transfer forefinger loops to thumbs by inserting thumbs into loops from below and withdrawing forefingers.

5. Bring up wrist loops to position 1—that is, round thumbs and little fingers, making palmar strings.

6. Repeat 3, taking care to keep all strings on thumbs.

7. Bend middle, ring, and little fingers over far little-finger strings, and bring the two far strings towards you by turning palms towards you till the far strings touch the other strings of the figure.

8. Remove thumbs, and reinsert them into their loops from above, then putting them under the two strings just brought forward. Take these strings on their backs and straighten thumbs. Release little fingers. (There are two loops on the thumbs : of one, the far string makes a palmar string; of the other, the near string runs to the centre of the figure.)

9. Lift over tip of thumbs and drop on palmar side the loops whose far strings run towards centre of figure, and separate hands, when two diamonds slide to the left, two to the right.

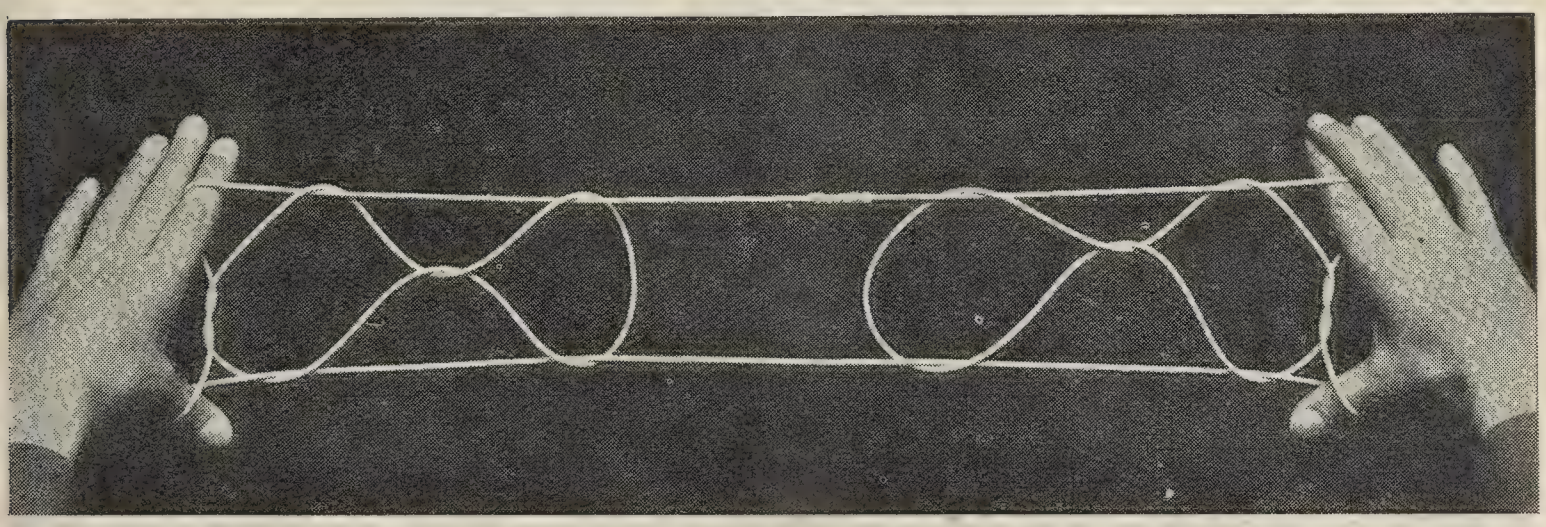

FIG. 3.—Unnamed.

In the figures *kaha-kuranui* (see later) and *tahitinui* we have four diamonds. All are formed of crossed strings in the former, whilst in the latter the two central strings are crossed, those on either side being looped. There is a figure in which the two central strings are looped, the others crossed—"Ouleoulé and the bird-lime."†

1. Loop on thumbs only.

2. Bring right little finger forward over thumb loop and down on near side of near thumb string. Hook up that string, and carry it away ; raise little finger to its position, with string forming a near little-finger string after circling little finger.

3. Left little finger under right palmar string, and carry it back, forming a left little-finger loop.

4. Thumbs into little-finger loop from below, and return, carrying near little-finger string on backs.

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* Mrs. Jayne, *loc. cit.*, p. 176. † Compton, *loc. cit.*, pp. 227–28.

5. Forefingers into thumb loop from below, and return, carrying far thumb string on backs.

6. Extend, by turning the palms away. The loose hanging string is the bird-lime.

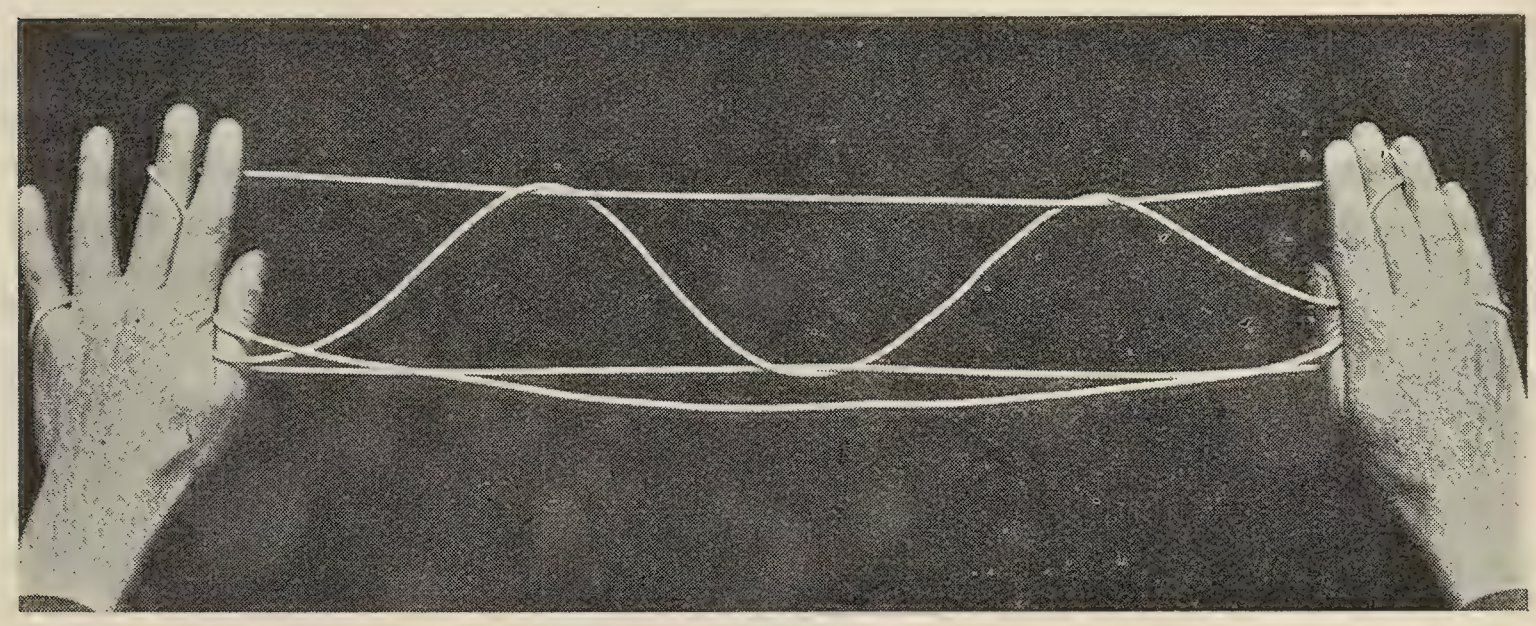

FIG. 4.—The bird-lime.

7. Some one now comes and says to Ouleoulé, "Put it on top." Lift the slack string over tips of thumbs and drop it on palmar side; close tips of thumb and forefinger of each hand, and transfer forefinger loop to thumbs.

8. Forefingers into thumb loop from below, and return, carrying far thumb string on backs.

9. Extend as before by turning away palms, and the bird-lime is now on top of a triangular figure representing a tree.

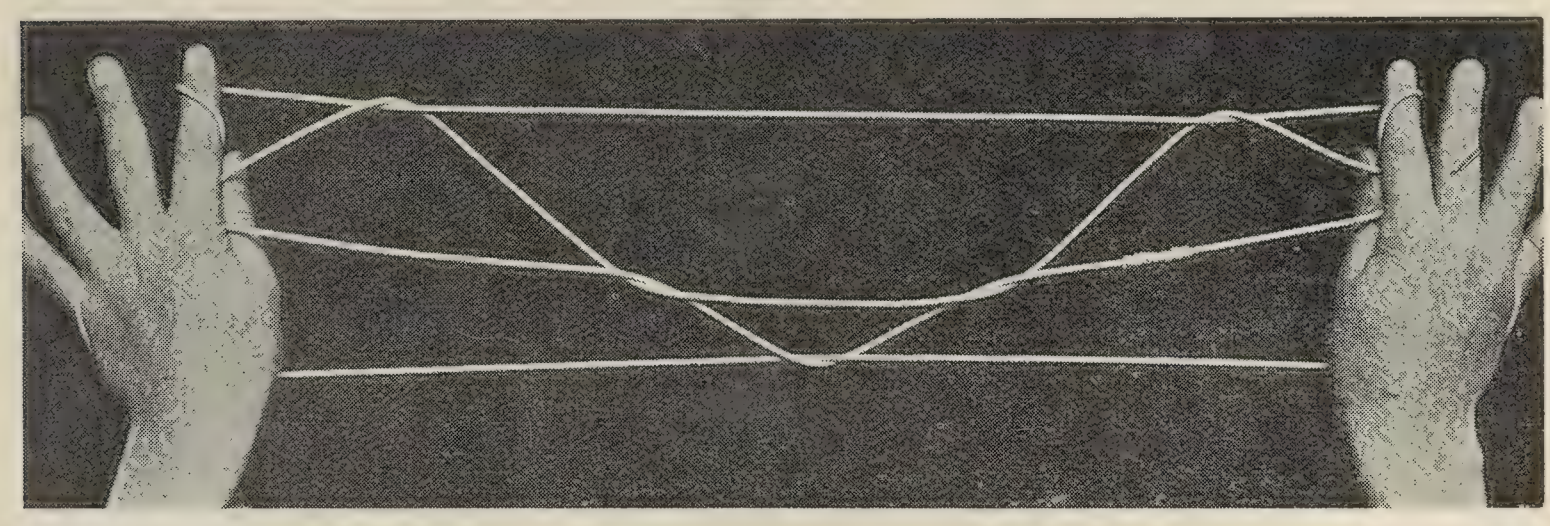

FIG. 5.—Bird-lime on the tree.

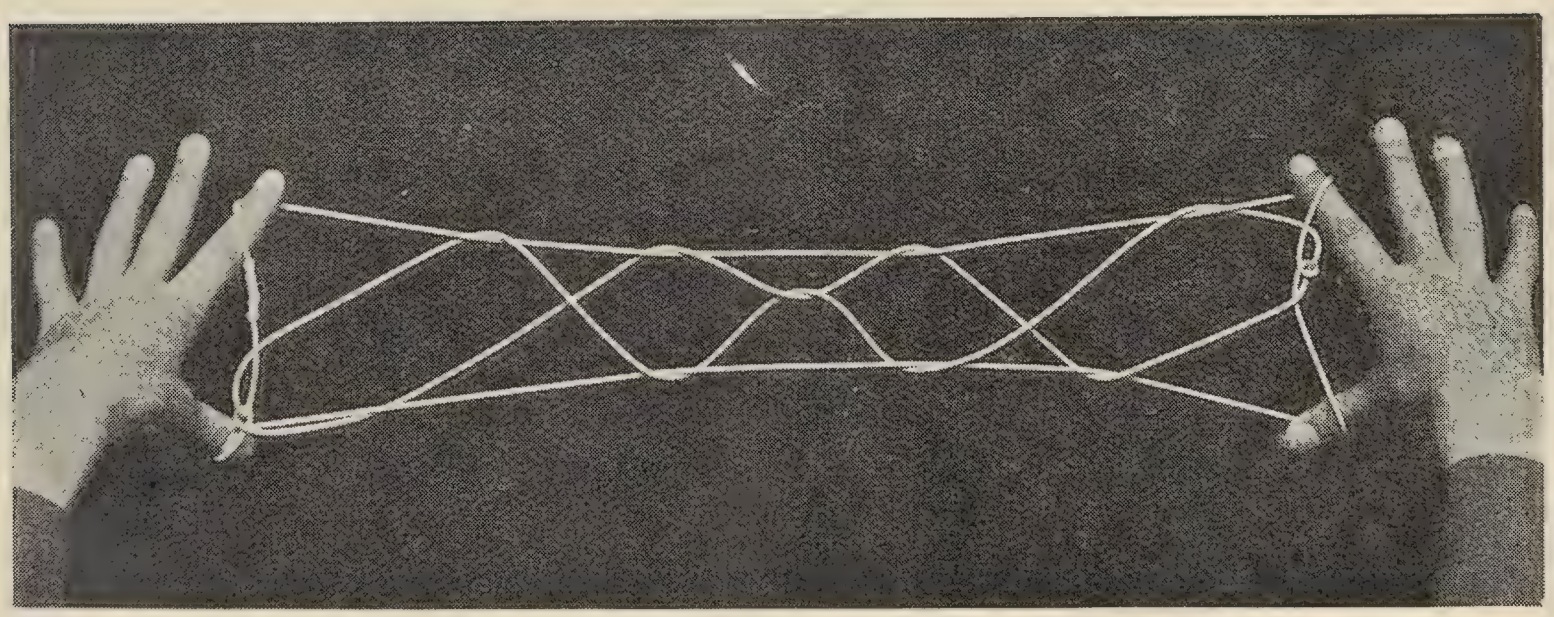

FIG. 6.—The four pigeons.

10. Navaho thumbs (that is, lift lower thumb loop past upper thumb loop and drop it over tip of thumb), release little fingers, and spread forefingers and thumbs, extending figure again by turning palms away. The four diamonds represent the four large pigeons caught by Ouleoulé.

TE KURI A TUATINI.

(From Whaare-mutu, a Tuhoe woman.)

Synonyms : TE KURI RUARANGI (Tuhoe) ; TE KURI POU TUATINI (Tuhoe) ; TE PA-HARAKEKE (the flax-cultivation), (Te Kiwi-amohau, Arawa Tribe, Ohinemutu). The figure was also shown to me by H. Ruru (see fig. 7), but he knew no name for the first part.

FIG. 7.—Harry Ruru, of Gisborne, from whom several figures were obtained.

First Figure.

1. Opening A.

2. Twist all the loops once, turning fingers and thumbs first away from you, then down under loops from far side and towards you, in so doing. It is a help, when the thumbs are turning, to hold the extended strings against the breast ; also, the thumbs should be held down on the forefinger loop whilst the little fingers are turning, and the little and ring fingers should be closed on to the palm whilst the forefingers are turning. If a loop slips from a finger it is always safer to begin again.

3. Transfer thumb loop to forefingers, the forefingers entering the thumb loop from below.

4. Thumbs through lower forefinger loop from above, and into little-finger loop from below; take on their backs the near little-finger string, and return through the forefinger loop.

5. Release little fingers.

6. Thumb into upper forefinger loop from below; release forefingers from upper loop, so transferring it to thumbs.

7. Forefingers down past upper near thumb string on near side into lower thumb loop from above; take up on their backs lower near thumb string, and return, transferring the lower loop from the thumb to the forefinger.

8, 9. Repeat 6 and 7.

10. Repeat 6.

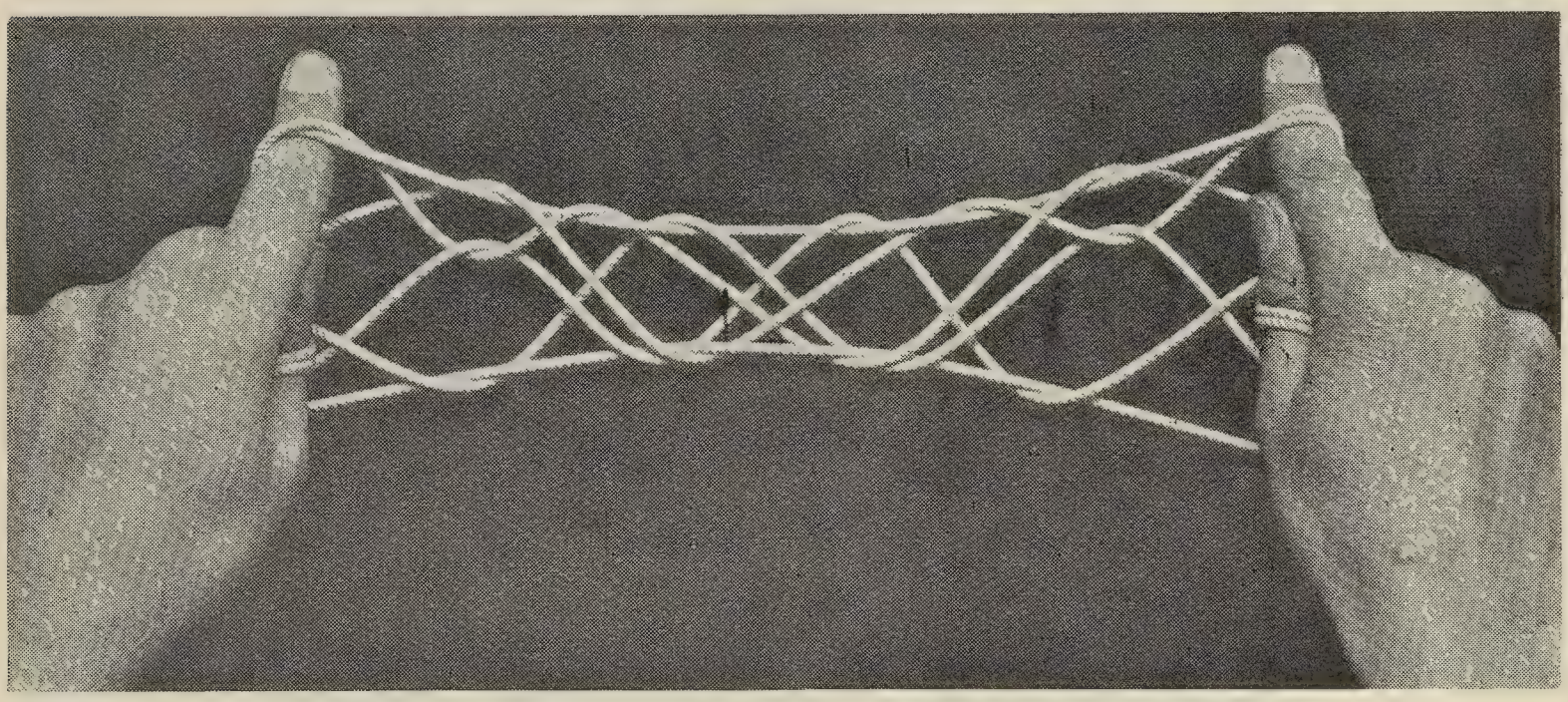

FIG. 8.—First figure of *Te kuri ruarangi* or *Te pa-harakeke*.

11. Movement 4 of *ikiiki*, viz.: Middle, ring, and little fingers under forefinger loop; with ring and little fingers hold down on palm the far double thumb string, and with middle finger inserted in forefinger loop from below, press down near forefinger string. Bend forefingers foreward over near double thumb string, grasp that string between forefingers and middle fingers, and draw it away from you through the forefinger loop, turning the palms away so that the far forefinger string slips over the backs and tips of the forefingers. Take care that the forefingers are kept well bent so that the double thumb string eventually rests on their backs. Extend by spreading the figure between forefingers and little fingers, thumbs held close against forefingers, the double string crossing their backs, round and across backs of forefingers.

Second Figure.

TE AHI I TUNUA AI TE MANAWA O NUKU-TAU-PARURU (THE FIRE AT WHICH THE HEART OF NUKU . . . WAS ROASTED).

(Tuhoe Tribe.)

Synonym: IPU TAHI (the first calabash), (H. Ruru, Ngati-Porou Tribe, Gisborne).

12. Bend forefingers down and up, catching on their inner side the single string crossing the forefinger loop close to the finger. Release little and ring fingers, drawing the loops taut. All are now held on the fore-fingers and thumbs.

13. Close disengaged fingers on to palm, holding down all the strings. Take the bundle of strings so held between the forefinger and thumb of both hands, draw hands apart smartly, releasing the fingers from the palms

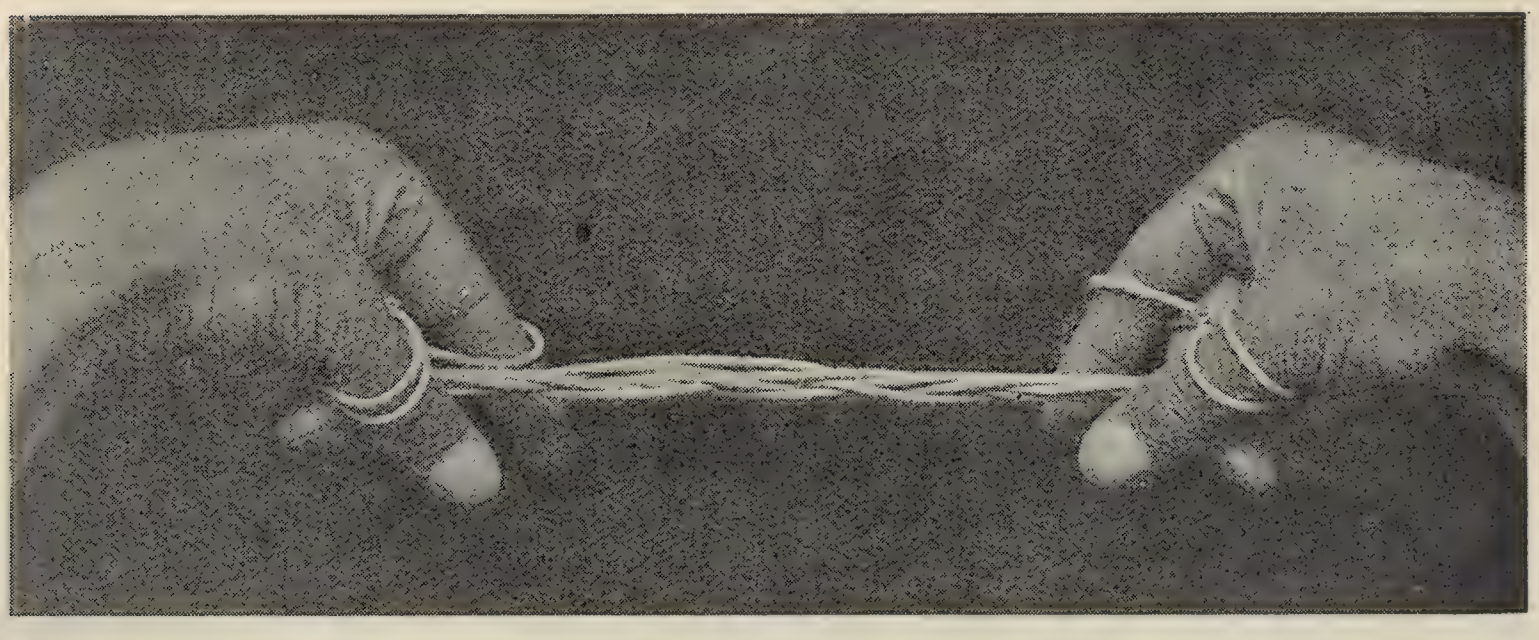

FIG. 9.—During movement 13.

in so doing, and taking care that no loops slip from the fingers. Hold all taut, turn the palms upwards, the thumbs passing under the forefinger loop as they reach their usual position. This movement releases one twist from the strings.

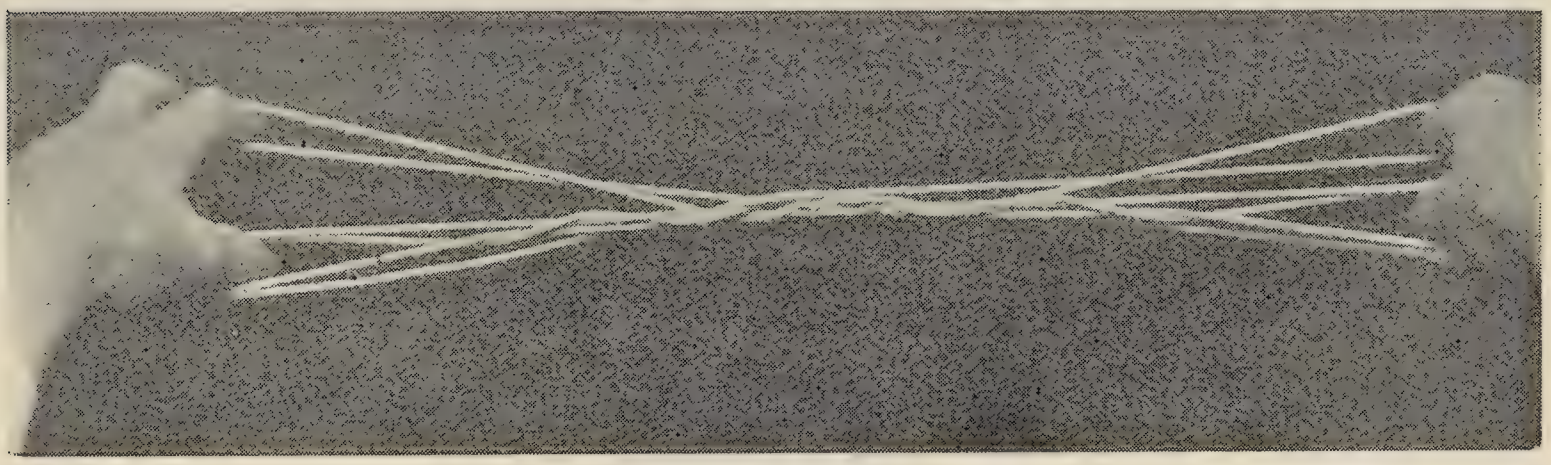

FIG. 10.—Towards close of movement 13.

14. Repeat movement 4 of *ikiiki*, and extend as before.

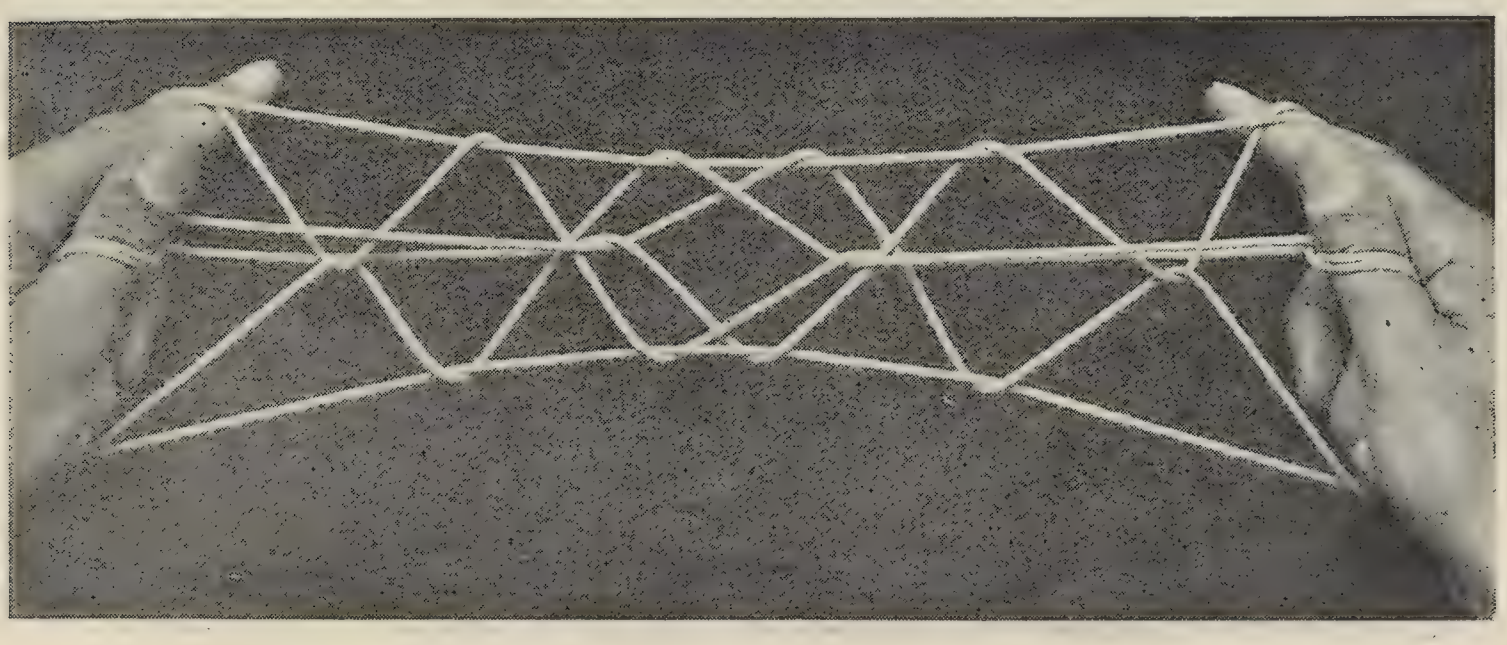

FIG. 11.—Second figure of *Te kuri ruarangi ; Te ahi i tunua ai te manawa o Nuku-tau-paruru ;* or *Ipu tahi.*

The central double diamond represents the fire, the pairs of strings running right and left from this diamond to the sides of the figure representing the spits (*huki*) on which the heart was impaled during the roasting.

Third Figure.

(No name, and produced only by H. Ruru.)

15. Bend forefingers down and up, catching the upper string of the spits. Extend.

16. Repeat movement 13 above, then movement 4 of *ikiiki*, and extend as before.

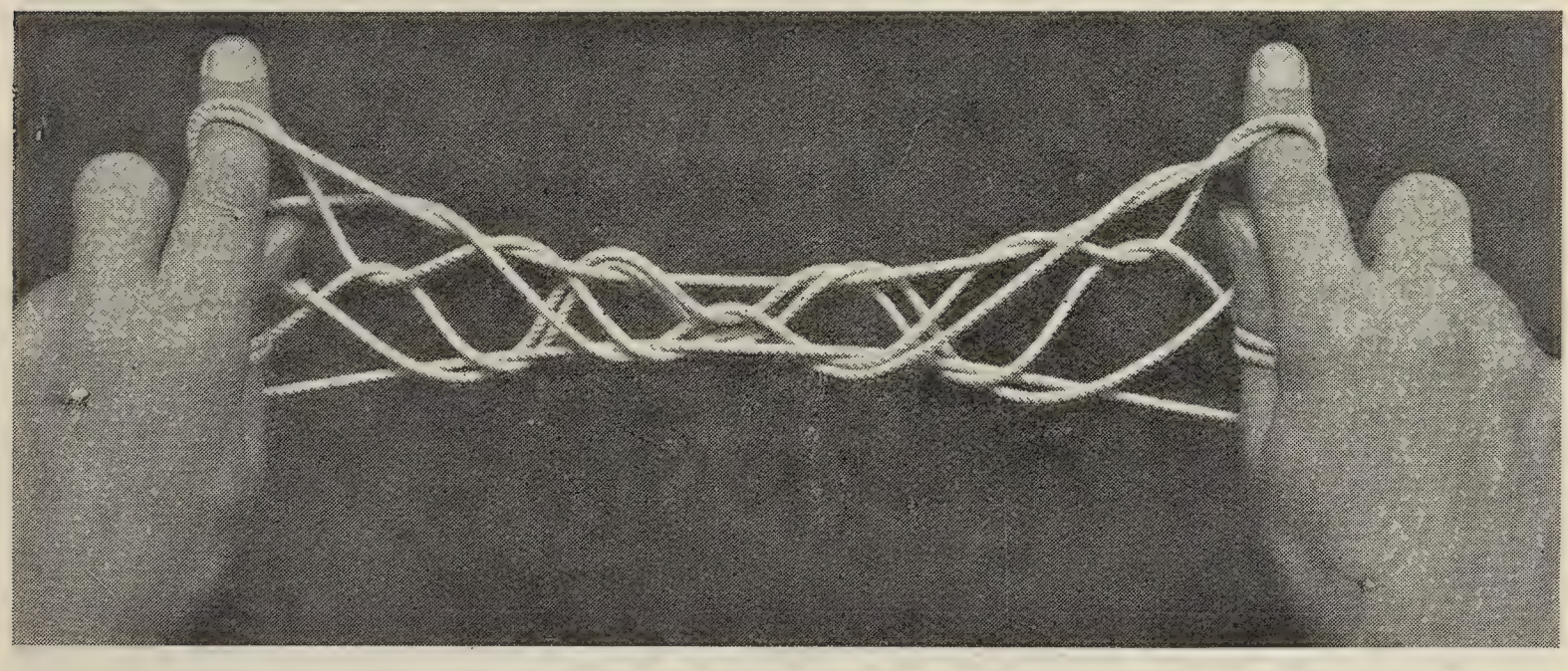

FIG. 12.—Third figure of *Te kuri ruarangi*.

I saw other variations, worked by the Tuhoe people, when a second person took the strings from the fingers of the first. I did not get the opportunity to take these down.

Fourth Figure.

A fine figure is produced in the same way as the figure *parahuhu* is produced from *ikiiki*, but I have never seen this produced by the Maori.

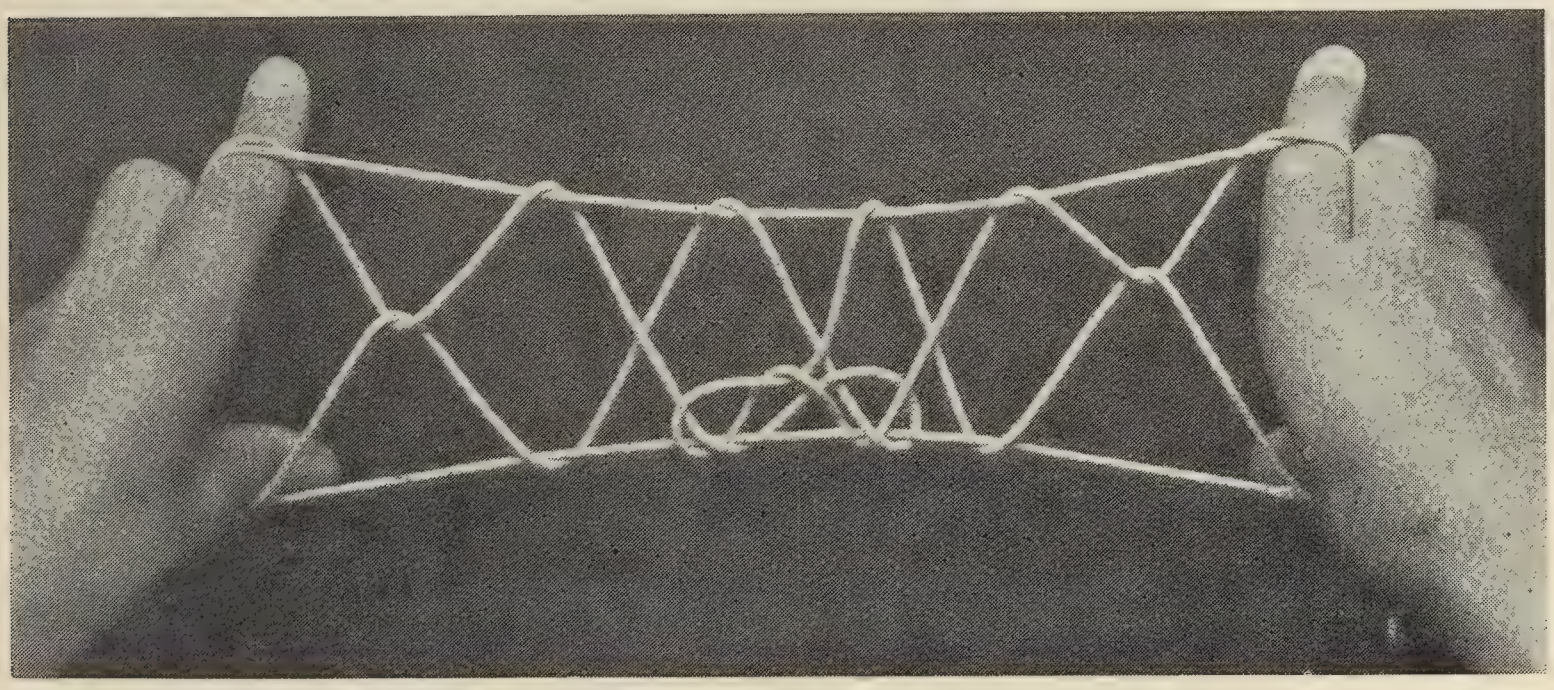

FIG. 13.—Fourth figure of *Te kuri ruarangi*.

At the villages up the Wanganui River—Koriniti, Hiruharama, and Pipiriki—the first figure is known as *pa-harakeke*. In Koriniti there were several of these *pa*—small enclosures where from twenty to thirty flax-plants grew to supply the constant need for blades in the manufacture of food-baskets, *kete* of all kinds, *kawe* or carriers, &c.—and the similarity of the figure to the radiating of the flax-fans at the butts of the plants was striking.

Up the Wanganui the loops were not twisted, movement 2 being omitted altogether. This results in quite different figures, and here there were four known to the Maori, as follow :—

First figure : *Pa-harakeke* (the flax-cultivation).

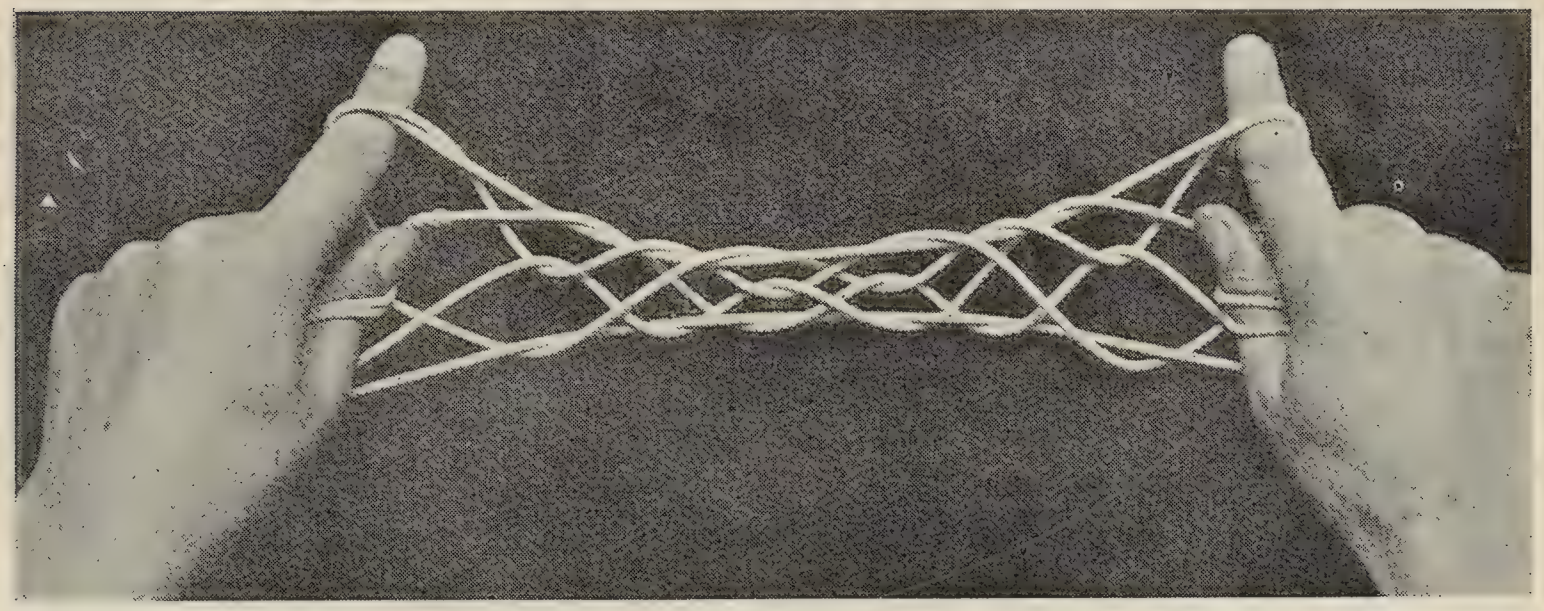

FIG. 14.—*Pa-harakeke* (untwisted loops).

Second figure : *Rakau-piko* (the bent stick).

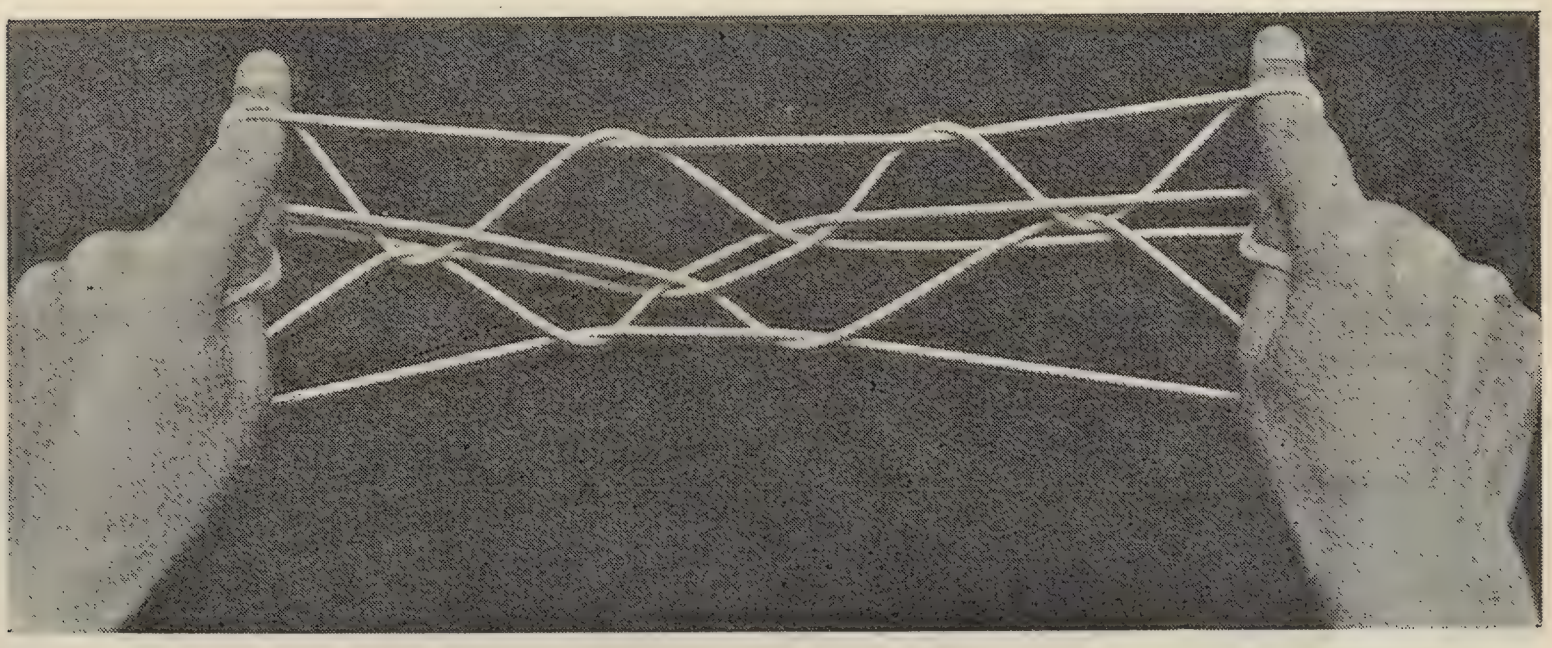

FIG. 15.—Second figure of *Pa-harakeke*.

The symmetry of the second figure of *te kuri ruaranqi* is here lost, and the name, *rakau-piko* (the bent stick), is appropriate.

Third figure : *Niho-reke.*

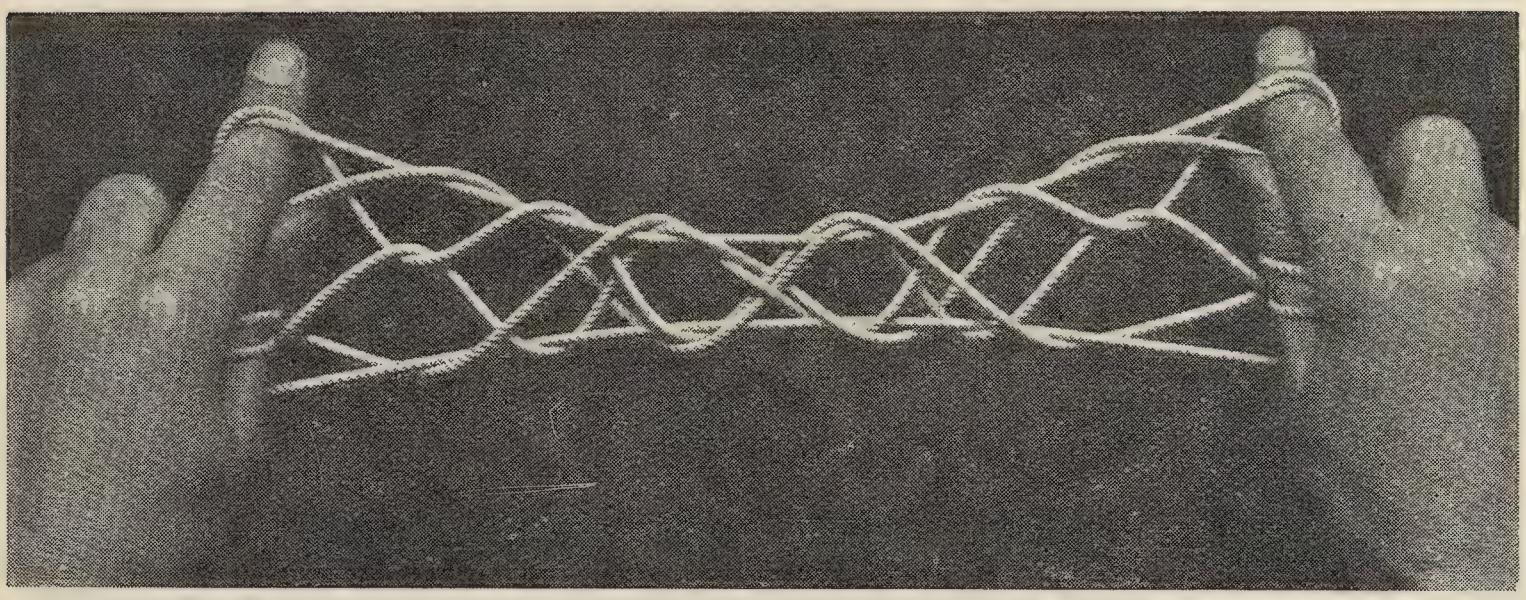

FIG. 16.—Third figure of *Pa-harakeke.*

This is almost the same as the first figure of *te kuri ruarangi.*

Fourth figure : *Koro-moana.*

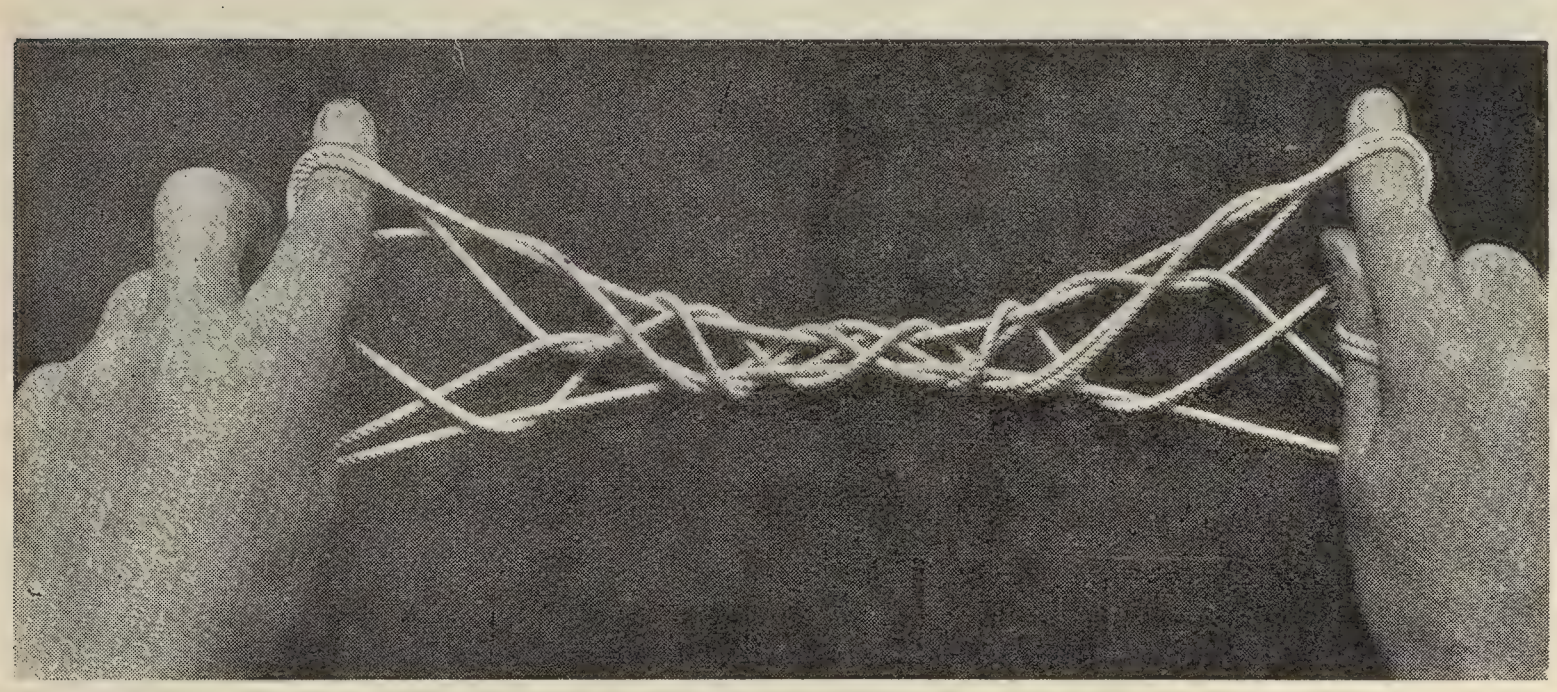

FIG. 17.—Fourth figure of *Pa-harakeke.*

The procedure for the production of the fourth figure is the same as for the second and third. The name *koro-moana* should perhaps be *koura-moana,* for the figure resembles one bearing the latter name (see later).

If it now be attempted to produce the fifth figure, a parallel to the fourth of *te kuri a Tuatini,* it will be found that the strings are not interlocked in the centre, but two moving figures result, the parallel of many Pacific and other figures, where symmetrical separating shapes are given names like "two lions," "two coyotes," "two elks," "two foxes," &c.

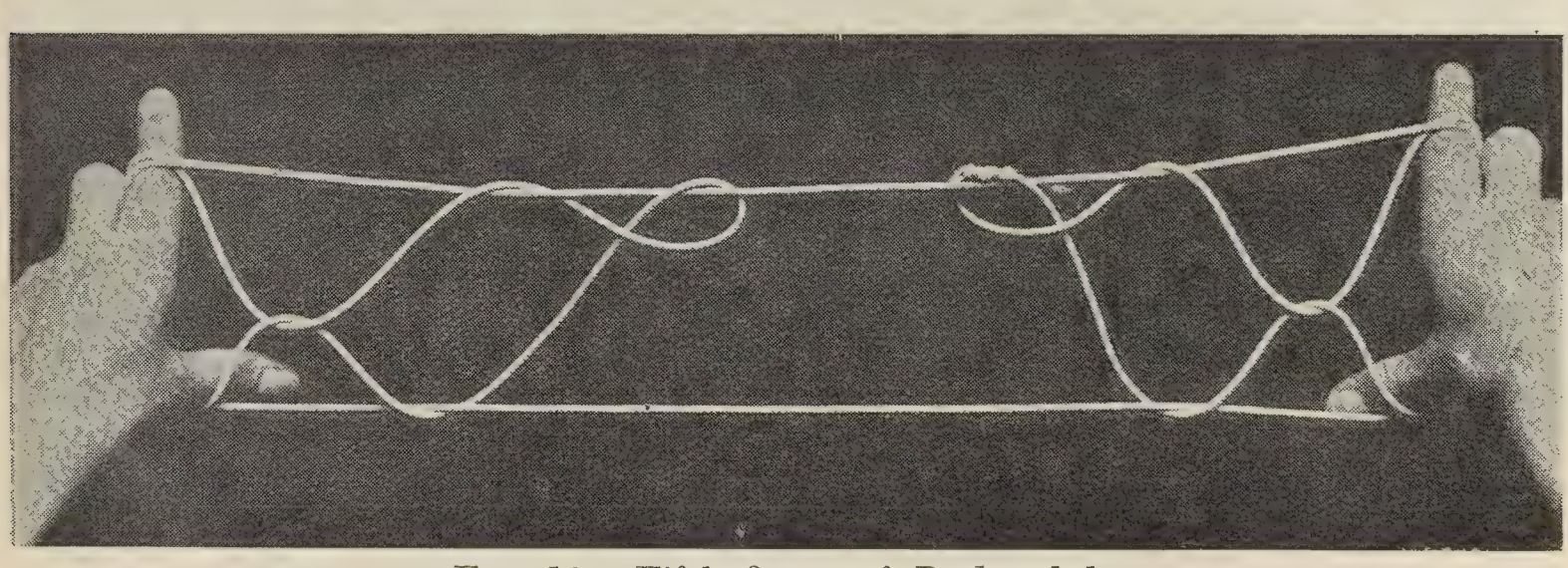

FIG. 18.—Fifth figure of *Pa-harakeke.*

This figure may be produced at any time after the first figure has been formed. In the illustration the small loops should be round the lower, not the upper, string.

KOURA (CRAYFISH).

(From Whanganui people at Koriniti.)

1. Opening A.

2. Thumbs over forefinger loop, under little-finger loop, and return, carrying with it both little-finger strings, but not releasing little fingers.

3. Middle fingers into thumb loop from below, and return, carrying up the far thumb string. Release thumbs.

4. Thumbs into forefinger loops from below, and up into middle-finger loops. Transfer middle-finger loops to thumb, and carry them down through forefinger loop.

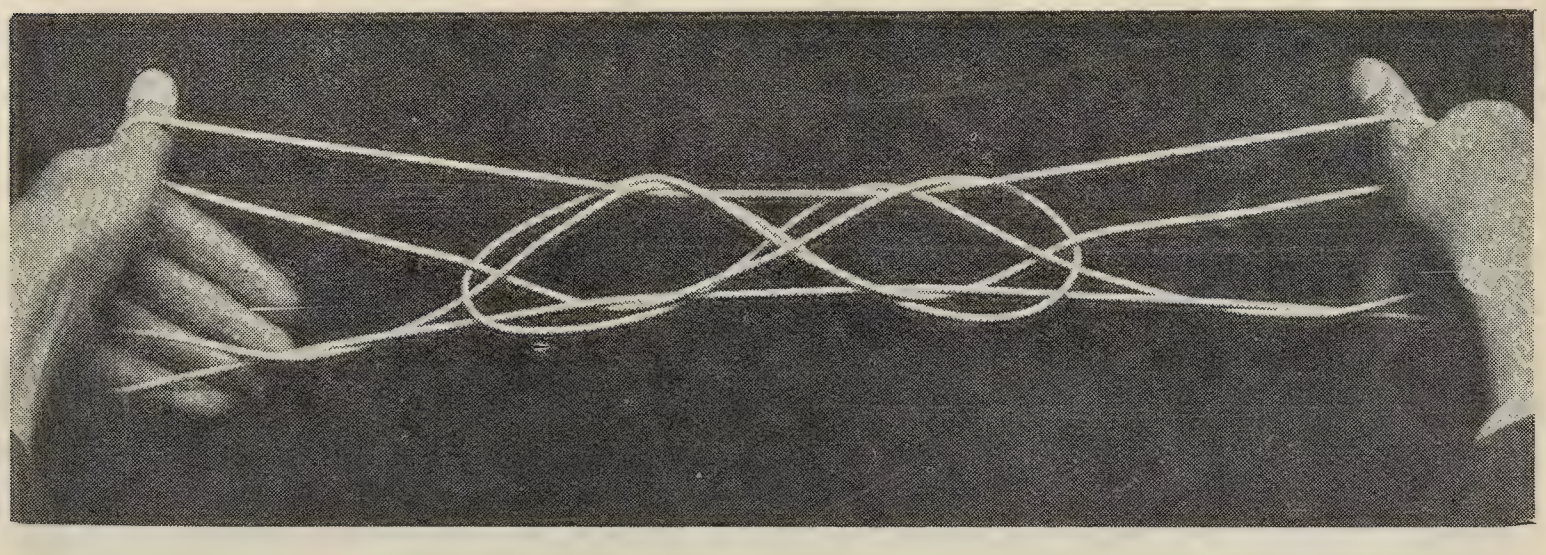

FIG. 19.—KOURA.

5. Release forefingers, and extend between thumbs and little fingers. Take care not to draw figure taut. (It is better extended if the thumb loops are first transferred to the first phalange of the forefingers, the thumbs then being used to press down the little-finger loops, as in *koura-papatea* following.)

KOURA-PAPATEA (FRESH-WATER CRAYFISH).

1, 2. As in *koura* above.

3. Forefingers down into thumb loops; turn palms outwards as forefingers return to position, carrying all thumb loops with them and leaving thumbs free.

4. Thumbs into lower forefinger loop from below and up behind the far string of the upper forefinger loop. Join forefingers and thumbs, and bend forefingers so as to allow their upper loop to slip on to thumbs, and allowing the middle and lower strings to slip off the fingers to palmar side.

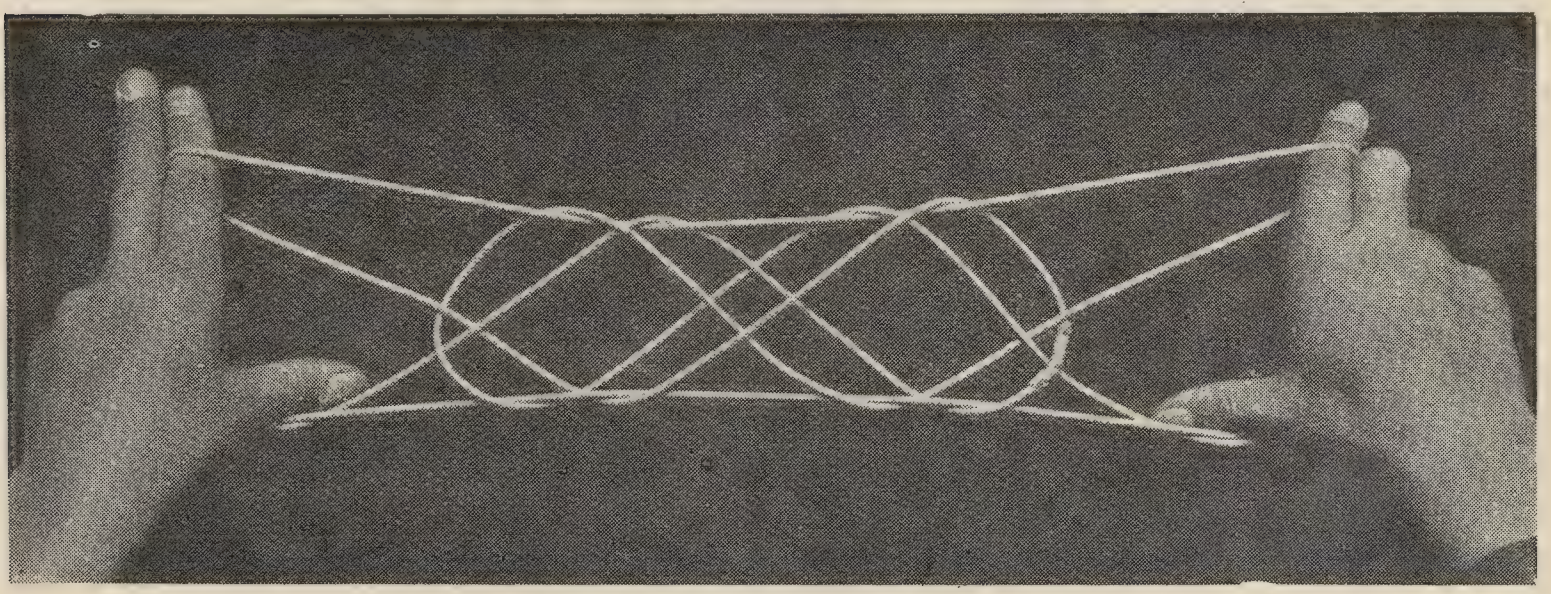

FIG. 20.—*Koura-papatea.*

5. Forefingers into thumb loop from below, and transfer thumb loop to forefingers.

6. Thumbs into both forefinger loops from below, remove forefingers from upper loop, so transferring it to the thumbs. Join tips of forefingers and thumbs so that lower forefinger loop slips over backs of fingers to palmar side.

7. Forefingers into thumb loop from below, and remove thumbs, transferring loop to forefingers.

8. Extend between forefingers and little fingers, the thumbs helping by pressing down the little-finger loop. The figure must not be drawn tight.

Excepting for movements 7 and 8, this figure, *koura-papatea*, is the same in procedure and result as a Caroline Islands figure *bur-bur-ani jau*, collected by Dr. Haddon, and called " circles and triangles " by Mrs. Jayne.* It is extended between thumbs and little fingers.

KOURA-MOANA (SALT-WATER CRAYFISH).

1–4. The same as 1–4 of *koura-papatea*.

5–11. The same as 2–8 of *koura-papatea*.

The movements are, in fact, exactly the same, movements 2–4 being made twice instead of once.

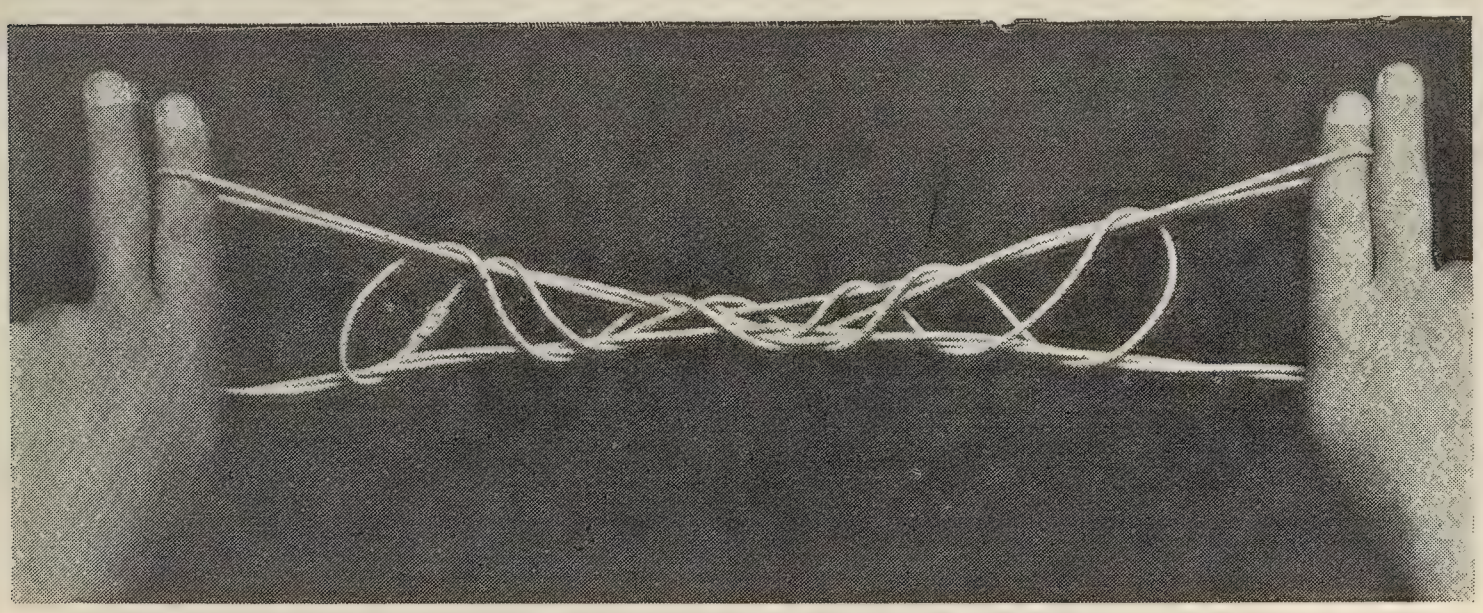

FIG. 21.—*Koura-moana*.

A Waikato youth, living at Hiruharama, set up a third figure, in which movements 2–4 were repeated three times. He knew no name for it. It is not figured, being too twisted up to be effective. May there be a connection, or confusion, between this name and *koro-moana*, the fourth figure of *pa-harakeke ?*

KOURA AND KOTIRO-PUNARUA.

(Both from an elderly Whanganui woman at Hiruharama.)

This is the best method of producing *koura*.

1. Opening A.

2. The same as 2 in *koura* above.

3. Forefingers into thumb loop from below, and return, carrying far thumb string on backs. Release thumbs.

4. Thumbs into lower forefinger loop from below, close thumbs and forefingers on upper near string of forefinger loop, bend forefingers, allowing lower loop to slip over their backs, and extend between forefingers and little fingers, thumbs helping as before by holding down little-finger loop.

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* Mrs. Jayne, *loc. cit.*, 146–49.

Continuation : KOTIRO-PUNARUA.

1. It will be noted that the little-finger loop has a twist. Release this twist by turning the little fingers towards you, down, away from you and up to their position, taking care that the loop does not drop from them during the movement.

2. Lay the figure across the knees. Insert the four fingers of the left and right hands downwards into what was the little-finger loop, and the thumbs into the thumb loop. Insert little fingers from below into the loop that passes under the thumb loop and over the little-finger loop, and spread hands, drawing strings taut. (The little fingers catch these loops only in order to keep central part of figure open until extension.)

3. Forefingers into thumb loop from above, and return, carrying near thumb string on backs.

4. Release little fingers, and extend, holding fast between forefingers and thumbs, at their roots, the double string consisting of the lower string of the upper loop and the upper string of the lower. Working the hands up and down will help the figure to form in the centre.

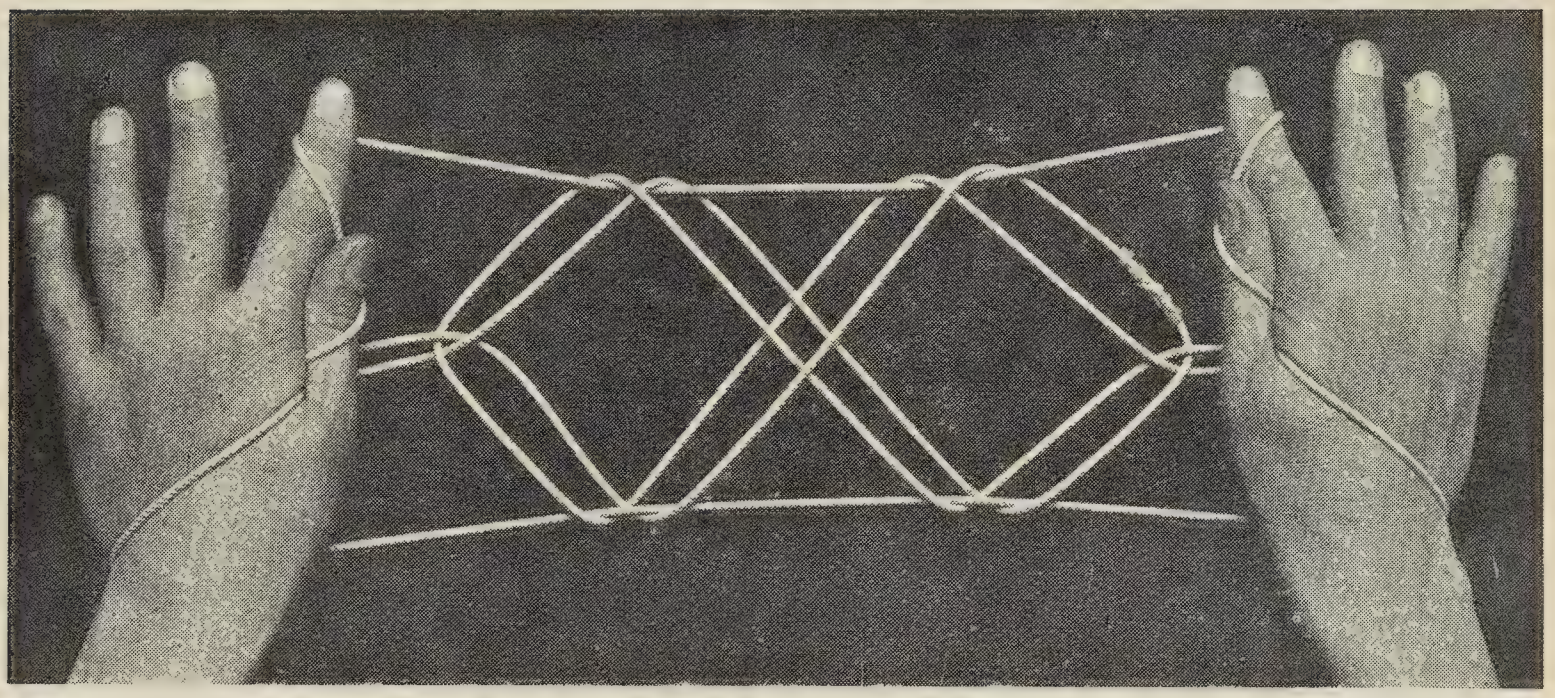

FIG. 22.—*Kotiro-punarua.*

There was a good deal of confusion regarding this name and the two *koura ;* some knew one figure, some another, and names were misapplied, through faulty memory. The names finally adopted above are those that emerged after many settings-up of the series before and by many individuals, singly or in company. *Kotiro-punarua* was seen at Rotorua, but not secured ; it was seen the first night at Hiruharama, and its name at once secured so that it might be learned later ; but the woman evidently gave a haphazard name, for she was unable to set it up from that name subsequently. She went through her repertoire several times, but not until one night towards the end of the stay did she set it up again. Then she confessed she did not know its name ; but the procedure was secured. The name was learned from the Waikato youth above referred to.

It appears to be the same figure that was produced by Makurata and her husband Paetini,* working in concert, at Rotorua.

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* Paetini is the last survivor of the Orakau *pa* defenders. His wife was an ardent adherent of Te Kooti, but she and her husband turned round completely, became firm friends of the pakeha, and have supplied a very large quantity of ethnological material, including over four hundred songs, obtained from them by Mr. Elsdon Best, whilst they looked after his camp.

FIG. 23.

FIG. 24.

FIG. 25.

FIGS. 23–25.—*Kotiro-punarua*, produced by Makurata and Paetini at Rotorua.

TE AMO-TUPAPAKU (THE LITTER FOR THE CORPSE).

(From Mrs. Charlie Gough, a Whanganui woman, at Koriniti.)

1. Opening A.

2. Thumbs under forefinger loop and into little-finger loops from below; join tips of forefingers and thumbs; turn forefingers down into little-finger loop and up into thumb loop, transferring all loops to the forefingers, and releasing the little fingers.

3. Insert all other fingers into loops with forefingers, transferring loops to wrists.

4. Turn palms from you; then turn little fingers down behind far wrist string—the single string running from wrist to wrist—and take up that string on the sides of the little fingers next the ring-fingers.

5. Close little fingers and ring-fingers so that they grip the string between them; turn thumbs down behind far double wrist string and catch that double string on their backs, allowing the near double wrist string to slip over the backs of the hands. Return hands to position, fingers pointing upwards, when there will be a double loop on thumbs and a single loop on little fingers, all strings except one near thumb string being twisted in the centre.

6. Thumbs into little-finger loops from below, take near little-finger string on backs, and return to position.

7. Forefingers into thumb loop from below, take on the side of their tips the far double thumb string and return to position, holding the two strings close between thumbs and forefingers. Turn palms away and spread the figure.

The loose string hanging from thumb to thumb is the *tupapaku* (corpse), the figure of four diamonds being the *amo* (litter). The *amo* is very like the figure of *kaha-kuranui* (see later), except that the top string is double in the former and there is no loose string in the latter.

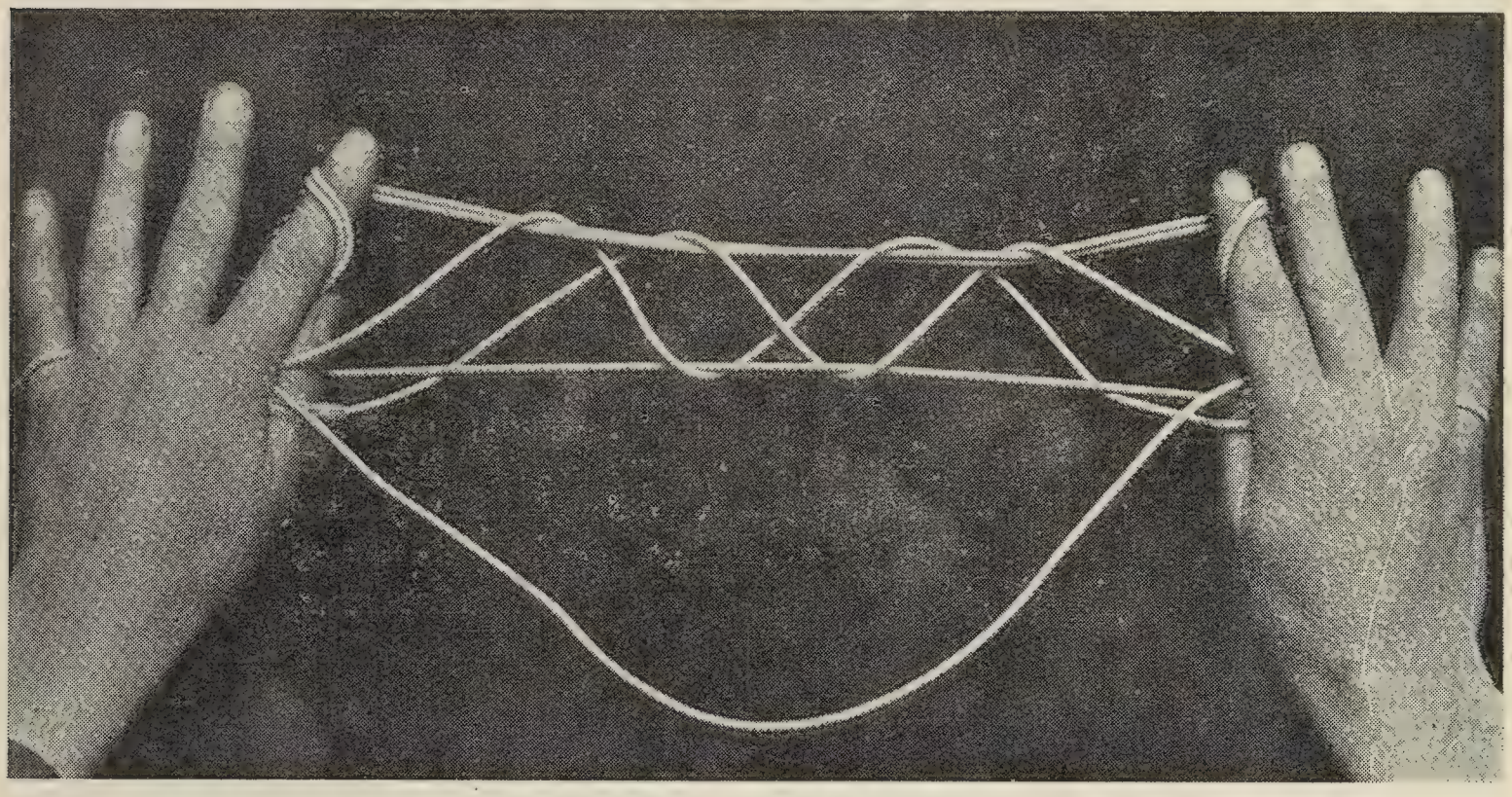

FIG. 26.—*Amo-tupapaku.*

PARORI.

(From Whanganui people at Koriniti.)

1. Opening A. (The left palmar string must be taken up first.)
2. Release little fingers.
3. Forefingers into thumb loop from below, and transfer the loop to forefingers.
4. Thumbs into lower forefinger loop from above, take far string on backs of thumbs, and return.
5. Thumbs into upper forefinger loop from above, take far strings on backs, and return.

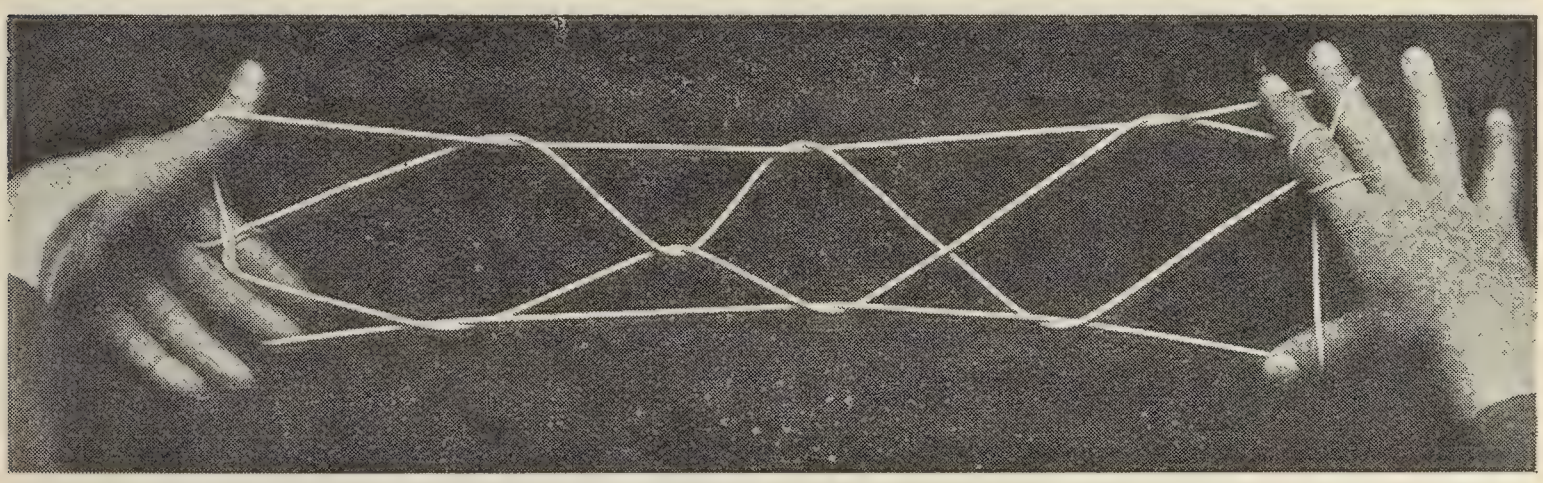

FIG. 27.—*Parori.*

6. Middle fingers down before the remaining (near) upper forefinger string, and behind the remaining lower forefinger string; take this lower string on their backs, and return.
7. Navaho thumbs—that is, lift lower thumb strings over upper strings and tips of thumbs and drop them on palmar side.

8. Turn the hands so that the back of the right hand is towards you, middle finger up and thumb down, well spread, and the palm of the left hand towards you, thumb up and middle finger down.

In construction this figure is identical with the "*bagobo* diamonds" from the Philippine Islands, but the extension is different, the former being vertical, the latter horizontal.

MOUTI.*

This figure is a universal favourite; and, whilst *mouti* is the name used elsewhere, it is known as *pionioni* up the Wanganui River. *Pionioni* is the act with which the figure *mouti* concludes. The word *mouti* is said to mean "a trap," but perhaps only because it was used as a decoy to trap Kae. He it was who killed and ate Tutunui, the pet whale of Tinirau. Tinirau sent a party of girls from village to village to discover Kae, who disappeared after his act—there is a long story on the subject—and they were to recognize him by a gap where a tooth was missing. Coming to one village where sat a seeming morose old man, whom they suspected to be Kae, but who would not "ope his lips by way of smile," they devised all manner of games, and used all artifices, to make him laugh; but it was not until they set up *whai mouti*, and recited its accompanying intimate little *karakia*, that they succeeded: he laughed, and by so doing delivered himself into the hands of his enemy. This little story the writer learned from Mr. J. Cowan, who in turn learned it from the Arawa folk; and the truthfulness of the Arawa is a by-word.

At Koriniti an elderly Maori, Rangi-tahua, one day started the opening lines of a song composed by a man in the olden days. This man's wife in gossip with her friends had represented her husband as possessed of a certain abnormality; whereupon in shame he composed this song, attributing to her an abnormality yet more pronounced, singing it whilst sitting in a public place in the village. As he sang he enacted the final movement of *mouti*, keeping time with the to-and-fro movement of the string. Rangi-tahua did not recollect the whole song, but after long public consultation, in which some dozen men and youths took part, the song, a *taunu*, was reconstructed. Dr. P. Buck (Te Rangi Hiroa) secured the following transcript, together with the signification of the numerous technical terms employed:—

Onioni mai hoki tē hope o Huariki
Aue mai koe nau i ki mai ki te nui o te ūre
Akuānei au kā hāngahangā atu
E te rau tenei taku pāki
Kihei au ē Hīne i hope oni
Puta nūi puta rōa puta aweawe kau o rōto
Kihei i hikī te haeretanga atu o te ūre
Hamama mai tonu mai to putaputa rurenga a tē tamariki
Whare kura e Hīne
Kua awhe kau o raho kei raro te kotare
E ka korihi te hanga i tō kumu
E rongo ure nui e kotahi tonū
E ko te raho ka ruā
E ko te mimi ka tīra
Heoi ano tīni whētū ki te rangi

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* *N.Z. Jour. Sci. & Tech.*, vol. 3, pp. 89–91, 1920.

Ko te rite i to hangā
I te whanau tokomaha na Tikī
Tu ai te toā tauā i wāenganui o to tara, ka tūra noa
Nga kiri tāpā nga kiri rāhō
Ko te mimi ko te toto
Ka ruaki te poharatāngā
A tini ānā o hanga e Hine
Kotahi te rau ma whitū.

This is quite untranslatable. It abounds in terminology for which no equivalents exist except in the phraseology of anatomical experts, and specialists at that; so that were it rendered into English it would still be practically incomprehensible. It is an example of the extraordinary knowledge of the Maori in anatomical minutiae.

The vowels marked long are not so long naturally, but are here prolonged to accord with the rhythm. The keen sense of humour possessed by the Maori was shown here. After Dr. Buck had with great labour secured interpretation of the whole, one of the young men made a sudden request —"Now you sing it all in your language"—great merriment resulting on the request being modestly and courteously declined.

It is evident that there are stories connected with many of the figures, but most of the stories have been forgotten, as many of the figures have been forgotten. As much was gathered from a man at Ohinemutu: "There are a lot of them," said he, "and they all have their story"; as he spoke he set up *mouti* through *te whare o Takoreke*, and repeated the *mouti* stanza. "There is *te mokai a Tinirau*," he went on; "I don't remember it, but this is the story: There were two boys, and they were born together —they were twins—and they grew up together; and whatever the one did the other had to do. The one went out in a canoe, and the other had to go; the one sat in the bow, and the other had to sit in the stern; the one started paddling, and the other had to start, so the canoe just went round and round." Nothing further has been learned of *te mokai a Tinirau*, but it evidently has something to do with Tutunui, the pet whale of Tinirau, since one meaning of *mokai* is "a pet."

HAPUKU.

(Whanganui people at Koriniti.)

This figure is best produced either with a string of full length doubled, or with a single string of half the usual length.

1. Loop over thumb and forefinger of right hand, and over thumb only of left hand. Close the fingers of right hand on strings, holding them on palm; insert left forefinger downwards behind the string passing behind right forefinger and thumb; turn the finger from you and up, drawing out the loop as the hands are spread, the fingers of the right hand releasing the held strings. (The near thumb string and near forefinger string pass straight across, the far strings crossing diagonally between forefingers and thumbs.)

2. Ring, little, and middle fingers into forefinger loop from below; hold down the near forefinger string; with middle fingers hold down far thumb string. Take near thumb string between forefingers and middle fingers, and carry it back through the forefinger loop, allowing that loop

to slip to the palmar side. There is now a string (" string " always means double string if a double loop is used) coming from little finger up close to palm, crossing near thumb string to centre of figure. The near thumb string going under this string is still held between forefinger and middle finger, and looping round the back of the former makes a near forefinger string. Keeping thumbs close to forefinger, push them past that finger till they rest on middle finger, taking care that they pass between the forefinger and the string coming from upwards from the little finger. This string will now be lying against the side of the thumb towards the centre of the figure as the thumbs point away from you. There are now loops on forefingers, thumbs, and little fingers, the forefinger pointing upwards, well extended, the thumb lying against the middle finger, the little and ring fingers being pressed close against the palm.

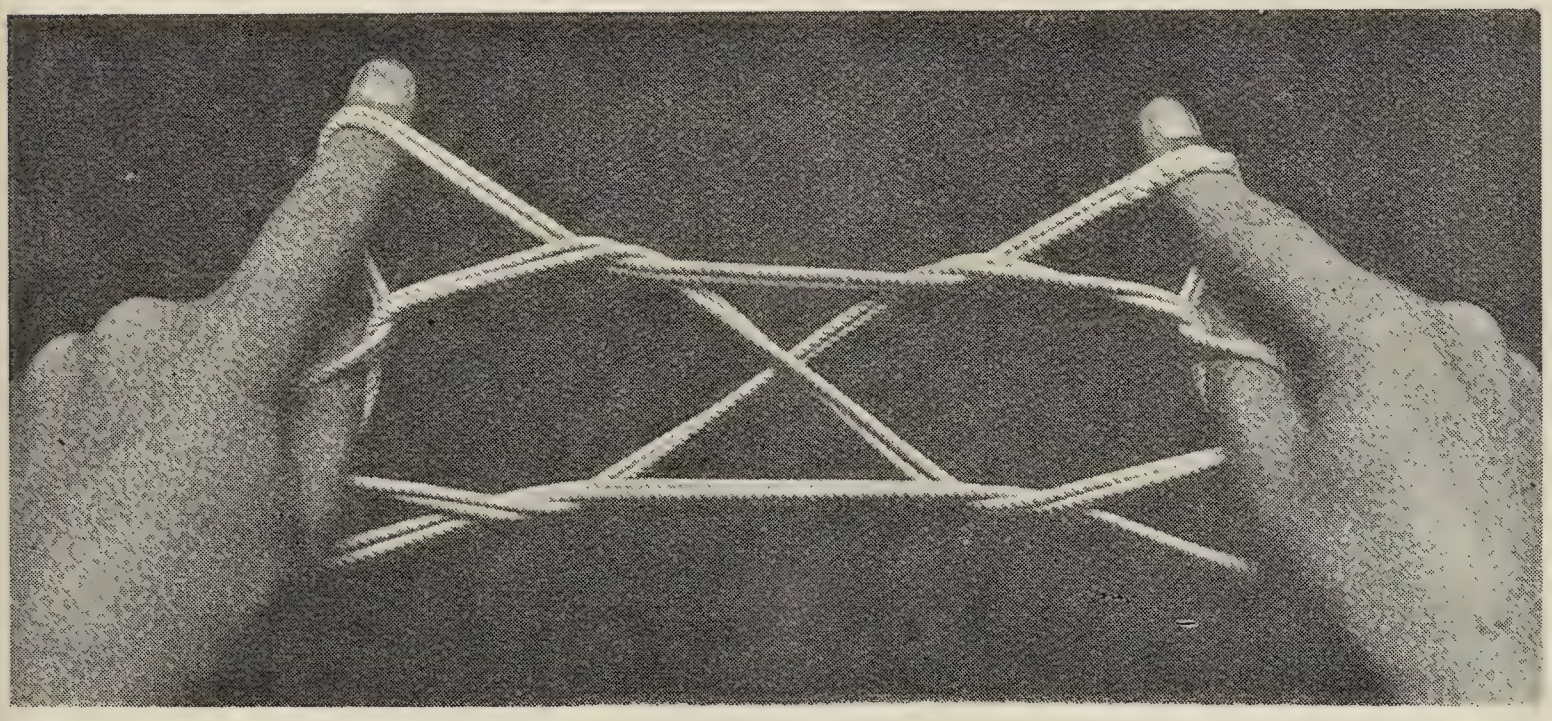

FIG. 28.—*Hapuku.*

With the thumbs held more forward, this was *pae-manu* at Pipiriki.

A more effective figure is produced if the thumbs are released in the above.

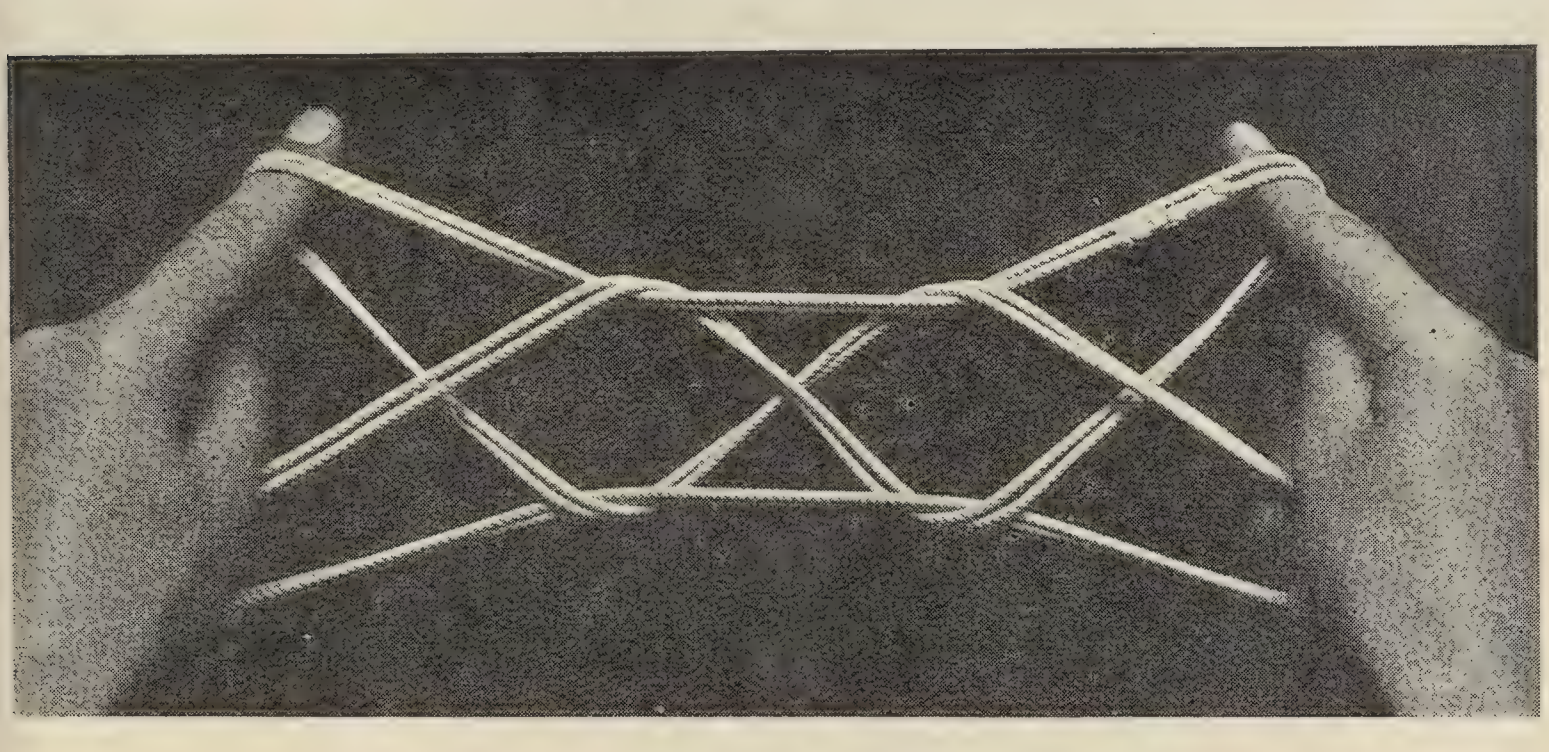

FIG. 29.—*Hapuku* with thumbs released.

TE WAKA A TAMA-RERETI.*

A new method of starting this figure was secured at Koriniti :—

1. Position 1.

2. Lips under near string, take far string between lips or teeth, drawing it towards you under near string.

3. Opening A, taking up the palmar strings with ring-fingers. Then as before.

KUMU-RURU (THE REAR OF THE RURU).

(From a young Taupo Maori living at Hiruharama.)

1. The loop, doubled to make it shorter, over little fingers only.

2. Thumbs under both strings, and return to position, leaving palmar strings on both hands.

3. Left forefinger under right palmar strings from below, drawing them out as in opening A.

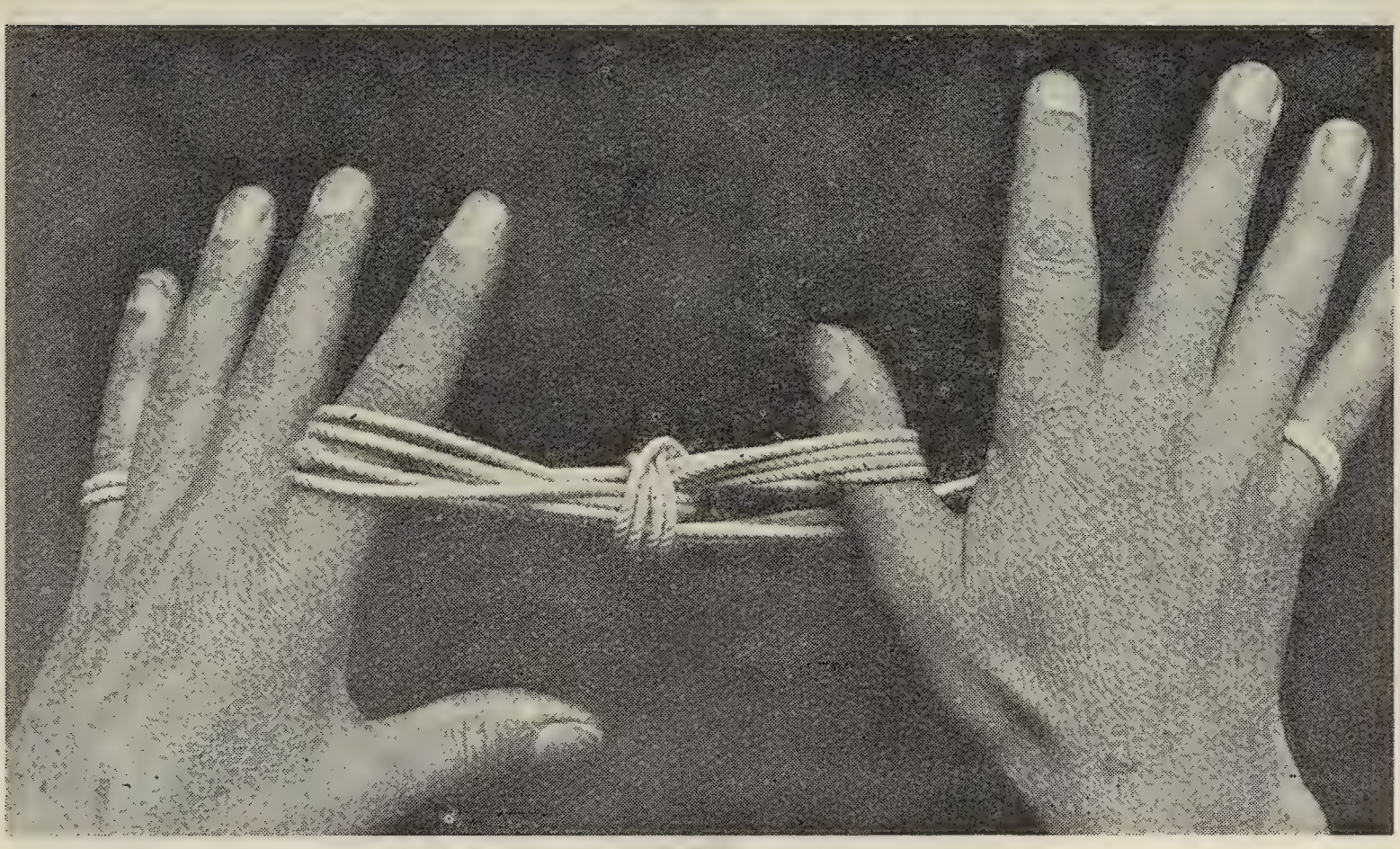

FIG. 30.—*Kumu-ruru.*

4. Right thumb over right little-finger loop and under palmar strings of left hand from below close to little finger, carrying strings back on returning.

5. Right thumb down into left thumb loop, and return, allowing left near double thumb string slip to palmar side. Remove left thumb from loop, draw taut, when a knot is formed around strings in the centre.

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* *N.Z. Jour. Sci. & Tech.*, vol. 3, p. 139, 1920.

THE COBWEB WHAI.

(From a Whanganui youth, at Hiruharama.)

At least three persons required for this.

1. A sets up *te tore* (= *te tore o Toi* = *kaheru* = Lochiel's dogs).

2. A and B draw out the loops, making the snare of Tama-te-kapua in the centre.

3. A and B now both set up *te tore* on the half of the cord held by them.

4. C now threads a cord through the eight loops on the fingers of A and B, and ties the circle, when the web is extended between them.

The effect is better if "the snare of Tama" is not drawn too close; and it is more like a cobweb if four persons hold the eight loops.

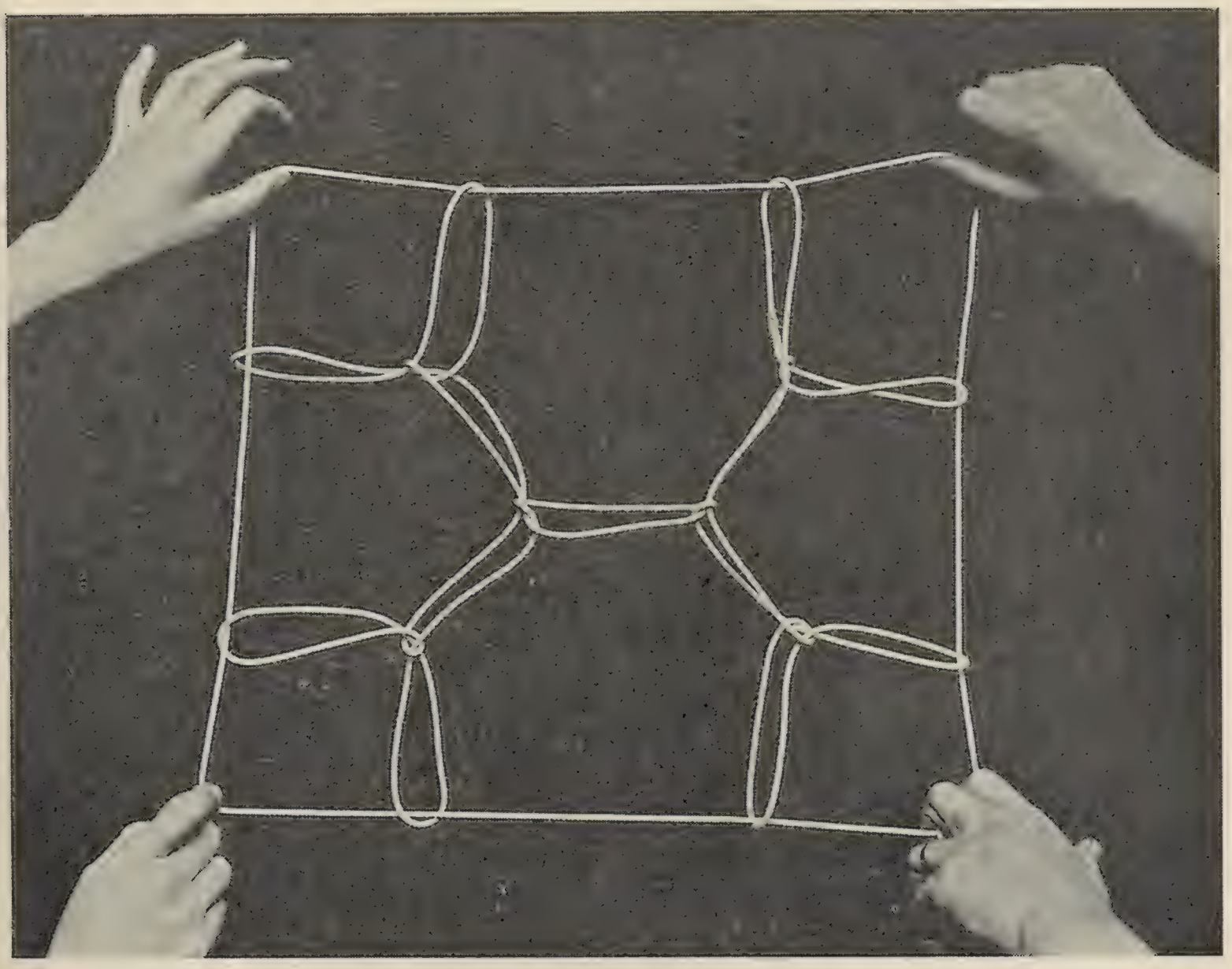

FIG. 31.—The cobweb *whai*.

ON THE HYBRIDITY OF *COPROSMA CUNNINGHAMII* HOOK. F.

By H. H. ALLAN, M.A., D.Sc., F.L.S.

I. INTRODUCTORY.

A. *General.*

"WHENEVER nature allows crossing evolution sets in; whenever crossing is made impossible it stops as soon as the segregation initiated by the cross is at an end." This striking and provocative statement of Lotsy in *Evolution by Means of Hybridization* (1916, p. 99) is indicativ. of the revival of interest in a comparatively neglected field of investigation—the occurrence of natural hybrids, and their bearing on the "origin of species" and the theory of evolution. While a vast amount of work on the hybridization of domesticated plants and animals has been done, owing to their extreme economic importance, the suggestive treatment of natural hybrids by Anton Kerner von Marilaun (in his fascinating work, *The Natural History of Plants*) was not followed up. Looked at askance by many, belittled by some, Lotsy's critical studies, however, have made it plain that there lies here a vast field for exploitation which cannot fail to reveal facts of the greatest significance in regard not only to the course of evolution in general, but to work in economic genetics. As Lotsy points out (*l.c.*, p. 42), "The problem of *Evolution* is not primarily, as is almost generally believed, the problem of the origin of species, but is *the problem of the origin of all those* INDIVIDUALS *of different constitution which people the earth.*

In New Zealand, Cockayne, as in so many other botanical matters, has been the pioneer in the field study of hybrids. Since his statement (1912, p. 30), "Hardly anything is known as to the occurrence of wild hybrids in New Zealand; but field observations on this head are, in any case, merely suggestive, and, at most, pave the way for experiment," he has advanced our knowledge considerably. One may instance the analysis of × *Myrtus Ralphii** (1918, p. 179). Still more recently most convincing evidence has been gathered of the remarkable amount of hybridism amongst our indigenous beeches (*Nothofagus* spp.). The publication of the detailed account of this research, as of the general paper in which is summed up the results of years of field study on hybridization in New Zealand, is eagerly awaited.

When one considers the evidence offered by many New Zealand genera —*e.g.*, *Clematis*, *Rubus*, *Veronica*, *Coprosma*, *Celmisia*—the various important lines of study thus opened up, and the far-reaching changes in outlook they will produce, become evident. Systematic studies will not consist merely in adding to the honoured labours of previous workers by descriptions of odd "new" species, but will require to utilize to the full the results of field-work and of the experimental garden. Critical analyses will be required of diverse forms and their causes, whether ecological or

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*Named hybrids are preceded by the sign ×; unnamed hybrids are indicated by the names of the parents, in alphabetical order, joined by × (the male parent has the sign ♂, the female ♀, when this is known): *e.g.*, *Veronica Hectori* ♂ × *pimeleoides* ♀.

genetic; and a "variety" will no longer be in danger of being treated as trivial, but will be regarded as of the utmost significance. In such intensive systematics the analysis of hybrid forms will play a prominent part, and as a preliminary much field-work lies ready to hand. From such studies will come the material for testing that revolutionary dictum of Lotsy (*l.c.*, p. 41), "inheritable variability does not exist." This paper is a small contribution to the preliminary work.

B. *Special.*

Hooker (1867, p. 113), when publishing *Coprosma Cunninghamii*, stated that it is "An extremely variable plant, perhaps a form of *C. robusta*, but very different-looking, with much smaller, narrower leaves, sessile flowers, and smaller fruit. In the *New Zealand Flora* I had confounded it with *C. propinqua*, to which it is very near, but differs in the fascicled female flowers, larger leaves, and branches rarely divaricating at right angles." Subsequent systematists—Cheeseman (1887, pp. 234, 246; 1906, pp. 249, 258), Kirk (1899, pp. 233, 241)—make similar remarks. That the facts of the case are best explained on the hypothesis that *C. Cunninghamii* is a hybrid of origin *C. propinqua* × *robusta* was suggested by Cockayne (1919, p. 121).

The present paper was made possible by the gift from Dr. L. Cockayne, Ph.D., F.R.S., of a series of specimens gathered by him in Deans's Bush, Riccarton. I wish to record here my grateful appreciation of the steadfast help and encouragement given me by Dr. Cockayne since, under his inspiration, I took up the study of botany. I have also to thank Messrs. T. F. Cheeseman, F.L.S., F.Z.S., F.N.Z.Inst., and H. Carse for much useful material for this paper, as well as most kindly help in the past. To Mr. A. H. Atkinson I owe thanks for kind permission to use valuable seedling material from his garden. For all statements made I must accept sole responsibility.

II. Morphology.

A. *Growth-form.*

Coprosma robusta is a bushy shrub or small tree, of upright habit, with somewhat spreading branches. *C. propinqua* is a densely divaricating shrub or small tree, with rigid branches. *C. Cunninghamii* is a bushy shrub, occasionally a small tree, of upright habit, with branches more rigid and less spreading than those of *C. robusta*, sometimes approaching the divaricating form. The branchlets of the three are decussate, the angle of divergence being approximately intermediate in the case of *C. Cunninghamii* between that of *C. robusta* (40°–50°) and *C. propinqua* (80°–90°) on the average of a number of specimens measured.

B. *Leaves, Inflorescences, Drupes.*

The following table gives details of certain of the flowering and fruiting specimens in my collection, and many more might be added making the series still more continuous. All lengths are given in millimetres. The term "cluster" is used for the groups of flowers, as in New Zealand coprosmas the terms "glomerules" and "fascicles" indicate different degrees of development of the inflorescences, not different modes of construction. Details of the morphology of the genus are given by Cheeseman (*l.c.*, 1887, p. 218).

No.	Leaves.	Inflorescences.	Drupes.
1	70–75 × 22–25, elliptic-lanceolate, subacute ..	2–5 clusters of 3–6 flowers, on peduncles ± 45 mm...	6 × 5, red, oblong.
2	60–70 × 23–30, elliptic-oblong, acute ..	1–2 clusters of 3–8 flowers, on peduncles ± 40 mm...	6 × 5, yellow-white, oblong, translucent.
3	60–80 × 25–30, elliptic-oblong, obtuse ..	2–5 clusters of 7–12 flowers, on peduncles ± 30 mm.	5 × 4, oblong, cream, translucent.
4	65–90 × 19–22, lanceolate-oblong, acute ..	1–3 clusters of 3–8 flowers, on peduncles ± 40 mm. ..	6 × 4, oblong, red-orange.
5	40–60 × 13–20, elliptic-oblong, subacute ..	1–5 clusters of 3–7 flowers, on peduncles ± 20 mm...	5–4 × 4–3, oblong, dark purple.
6	40–50 × 15–25, elliptic-oblong, acute ..	1–2 clusters of 2–6 flowers, on short arrested branchlets	6 × 5–4, oblong, yellow, translucent.
7	40–60 × 9–12, linear-oblong, subacute ..	2–5 clusters of 6–10 flowers, on peduncles ± 35 mm.	8 × 5, oblong, cream, translucent.
8	40–50 × 14–20, elliptic-lanceolate, acute ..	Male, 3–6, in clusters, on peduncle ± 10 mm. ..	..
9	30–35 × 6–8, linear-lanceolate, acute ..	1–3 clusters of 2–5 flowers, on short branchlets ..	5 × 4, oblong, red.
10	35–50 × 9–12, linear-oblong, obtuse ..	2–5 clusters of 2–6 flowers, on peduncles ± 20 mm...	4–5 × 3–4, oblong, cream, translucent.
11	35–40 × 8–12, elliptic-lanceolate, subacute ..	1–5 clusters of 3–9 flowers, on peduncles ± 15 mm...	5–4 × 4–3, subrotund, red.
12	30–50 × 6–10, linear-lanceolate, acute ..	Male, clusters of 3–12 flowers, on arrested branchlets	..
13	25–35 × 4–6, linear-oblong, acute	Clusters of 3–9 flowers, on arrested branchlets ..	4 × 3, rotund, mottled blue on cream base.
14	25–30 × 5–8, linear-oblong, obtuse	Clusters of 1–5 flowers, on arrested branchlets ..	5–4 × 4–3, rotund, cream, translucent.
15	20–25 × 4–6, elliptic-oblong, obtuse ..	Male, in clusters of 3–5 flowers, on arrested branchlets	..
16	20–30 × 4–6, linear-oblong, subacute ..	Male, in clusters of 3–5 flowers, on arrested branchlets	..
17	25–35 × 7–11, broadly oblong, obtuse ..	Clusters of 5–8 flowers, on arrested branchlets ..	5–4, oblong, red.
18	15–20 × 3–5, linear-oblong, obtuse	Clusters of 5–8 flowers, on arrested branchlets ..	4 × 3, white, translucent.
19	12–15 × 1–3, linear-oblong, obtuse	Male, in clusters of 5–6 flowers, on arrested branchlets	..
20	9–12 × 2–3, linear-oblong, obtuse	Clusters of 1–3 flowers, on arrested branchlets ..	5 × 4, oblong, cream, blue-stained.

Coprosma robusta is characterized by (1) large elliptic-oblong to elliptic-lanceolate acute leaves; (2) inflorescences of many-flowered clusters on stout axillary peduncles elongating in fruit; (3) reddish-orange drupes. *C. propinqua* has (1) small narrow-linear to linear-oblong obtuse leaves; (2) inflorescences of solitary or few flowers terminal on short arrested branchlets; (3) bluish-black drupes, rather smaller than those of *C. robusta*. As shown (fig. 1), specimens occur having many gradations of leaf size and shape, linking up the two species in a most complete way. The same is true of the development of the inflorescence, and of the size and colour of drupes. The linking-up of the inflorescences is sometimes obscured, as what appear superficially to be single clusters of flowers often prove on examination to be reduced cymes; nor is there always a clear-cut distinction between an axillary "peduncle" and an "arrested branchlet." In general, large-leaf and well-developed inflorescence go together, and less markedly red colour; as do small-leaf and less-developed inflorescence, with bluish mottling of the drupe. But the table and a large suite of specimens show that translucence of drupe can only arbitrarily be used as a point of specific difference for *C. Cunninghamii*. Translucence occurs with *robusta* type of leaves and inflorescences, and with those of *propinqua* type, as well as with "typical" *C. Cunninghamii*. Nor is red altogether absent from plants of *C. Cunninghamii* form. Drupes of *C. propinqua* differ in the amount of blue staining to the cream ground-colour, and sometimes are quite translucent. The *prima facie* evidence seems strong that we have two species hybridizing together, and forming a series of "intermediates," of which the middle members have been classed as *C. Cunninghamii* and the extremes as "variable" forms of the parent species.

III. The Seedling Plant.

Seedlings of *C. robusta* rapidly assume the adult form and size of leaf. A representative example showed the following: First leaf, 27 × 6; second leaf, 31 × 6; third leaf, 58 × 15; fourth leaf, 77 × 21; fifth leaf, 80 × 27 (fig. 2, A, B, C, D, E). So, too, with *C. propinqua:* First leaf, 6 × 1 second, 7 × 1·5; third, 8 × 2; fourth, 10 × 2 (fig. 2, F, G, H, K). My material, however, is insufficient in this case, and it must be pointed out that both species show epharmonic response to diverse conditions in their early life. In Mr. A. H. Atkinson's garden there grow several examples of *C. robusta*, and seedlings are frequent. There is also one plant of *C. propinqua*—a female. There have sprung up several specimens of *C. Cunninghamii*, several of which have reached young adult stage. Beneath the *C. propinqua*, and in the immediate vicinity, grows a mass of seedlings. Since there is no male *C. propinqua* in the garden or the neighbourhood, it seems very much more probable that these "spontaneous" examples of *C. Cunninghamii* are hybrids (so with the seedlings) than that in the one case *C. Cunninghamii* has been somehow brought from without, and that *C. propinqua* has received pollen from a male *C. propinqua* of unknown situation. The examination of the seedlings supports the hypothesis of their hybrid origin, and the facts observed lend great weight to the theory of the hybrid origin of *C. Cunninghamii* in general. Some two hundred of the seedlings have been planted out for further study. Fig. 2 shows representative leaves of a number of the seedlings, taken from plants not more than 100 mm. tall. The size ranges from 20–23 × 3–5 to 55–60 × 17–18. Of fifty measured, six were less than 30 mm. long, twenty-six were 30–39 mm.,

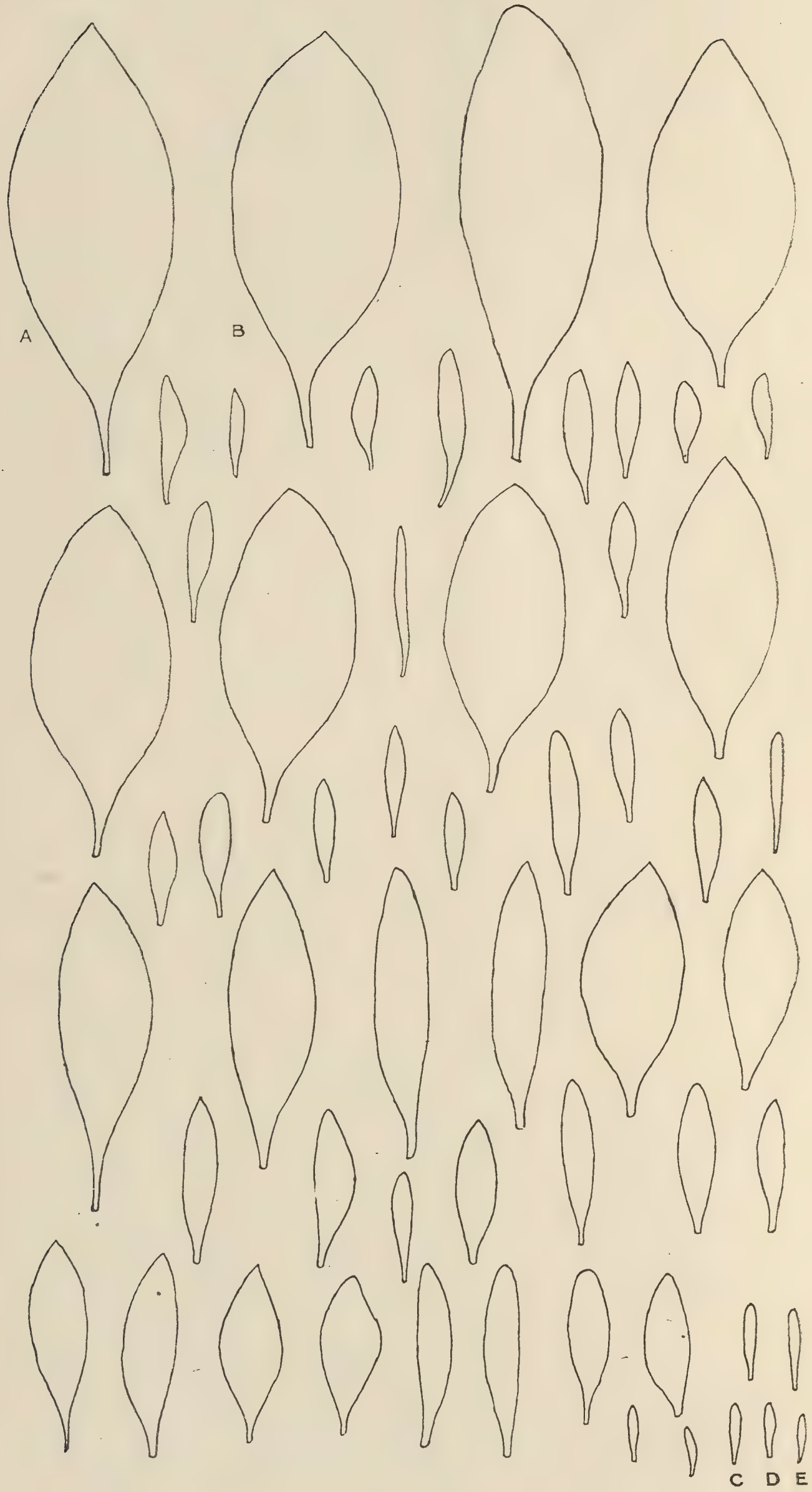

FIG. 1.

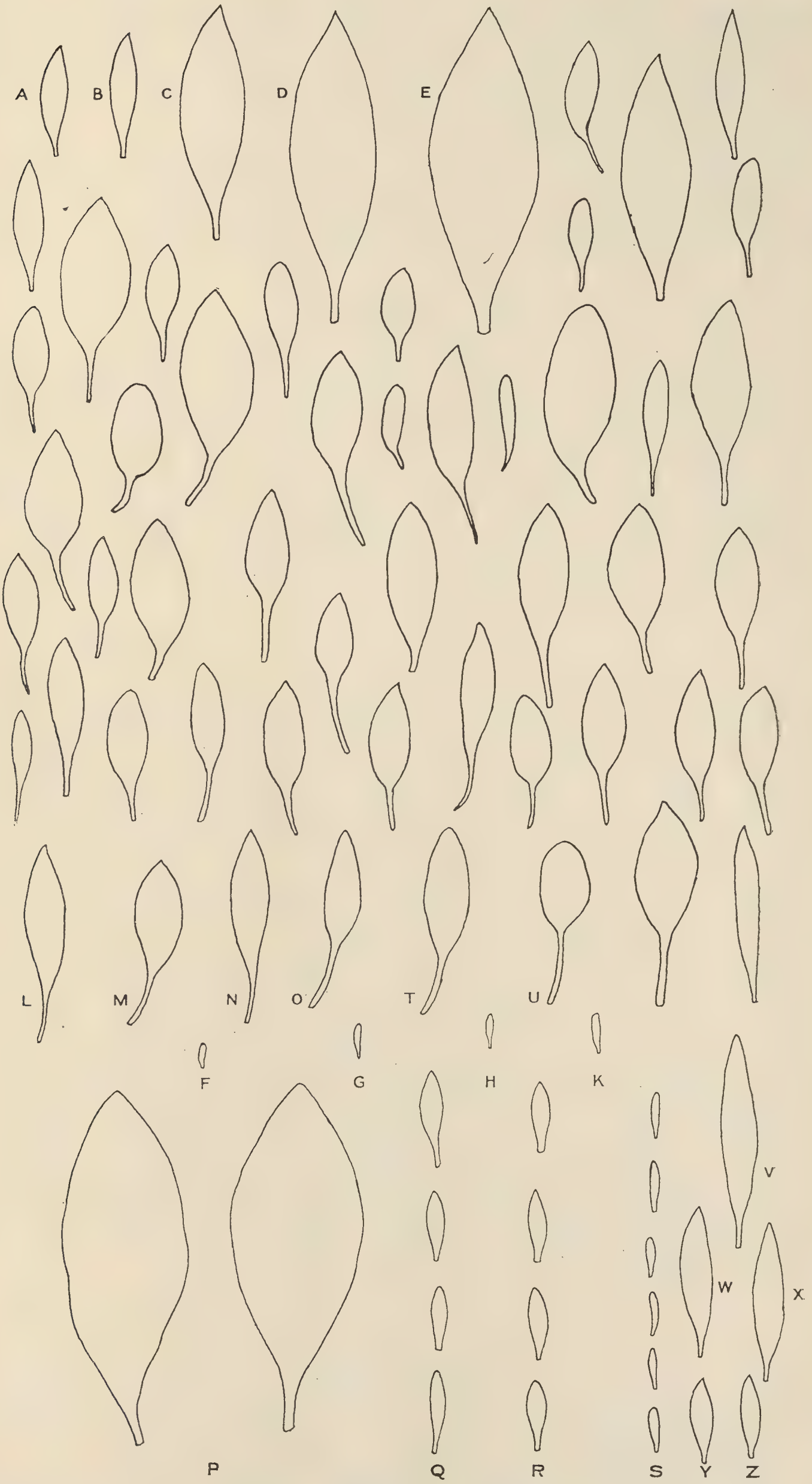

FIG. 2

twelve were 40–49 mm., and six were 50–60 mm. The shapes were from linear-oblong to elliptic, with a majority tending to elliptic-oblong. Long petioles were a distinct feature, in contrast to seedlings of both *C. robusta* and *C. propinqua*, this being probably an epharmonic response to the dense shade conditions under which the seedlings were growing. Such petiole-elongation I have witnessed in various seedlings.

The texture was thin. Shade forms of *C. Cunninghamii*, examined in several places, showed in the juveniles and young adults leaves of similar appearance and texture (fig. 2, L, M, N, O, T, U). A detailed analysis of the parent plants and two of the young adults follows (fig. 2, P, Q, R, S).

IV. DISTRIBUTION.

A number of indigenous plants of supposed hybrid origin are much more common in, or are confined to, places in which the alleged parents occur together: *e.g.*, *Myrtus Ralphii*, *Celmisia pseudo-Lyallii*. So far as my knowledge goes, this is true of *C. Cunninghamii*, and holds good even in comparatively small areas. For instance, in certain forest remnants near Feilding both *C. robusta* and *C. propinqua* are plentiful, and there, too, will be a good deal of *C. Cunninghamii*. In other patches one or the other supposed parent may be absent or rare, and then, too, *C. Cunninghamii* will be absent or rare.

V. CONCLUSION.

A consideration of the above data seems strongly to support the argument that *C. Cunninghamii* is a hybrid and to clear away the difficulties of placing various "intermediates." An examination of the specimens of *Coprosma robusta* var. *angustata* and var. *parva* in the herbarium of Kirk, their creator (*l.c.*, p. 233), shows that they match specimens I have here treated as hybrids. There are, however, but two small pieces of each variety, and it may well be that there are microspecies included in the conception of *C. robusta;* but herbarium specimens, even if much more copious, cannot establish such a contention.

I wish to thank Professor H. B. Kirk, M.A., F.N.Z.Inst., through whose courtesy I was enabled to study the coprosmas in the herbarium. It is recognized that the data here brought together are not crucial, and it is proposed to enter into the question more fully (*a*) by study of the seedlings already obtained, (*b*) by study of seedlings gathered from various forms, and (*c*) by controlled cross-pollination experiments. Although the hybrid origin of *C. Cunninghamii* seems to me much the most probable explanation of the facts, it is quite possible that there are included under the conception of *C. Cunninghamii* actual microspecies, notably the plant of the Mineral Belt, referred, with some doubt, to *C. Cunninghamii* by Cockayne (1921, p. 334).

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—	*C. robusta* ♂ (Fig. 2, P).	*C. Cunninghamii* ♂ (Fig. 2, Q).	*C. Cunninghamii* ♀ (Fig. 2, R).	*C. propinqua* ♀ (Fig. 2, S).
Leaves	80–92 × 31–38 (average 90 × 34), elliptic-oblong, subacute	14–25 × 3 – 7 (average 19 × 5), linear-lanceolate, subacute	16 – 25 × 4 – 8 (average 20 × 6), lanceolate-oblong, obtuse, subacute	8 – 12 × 1·5 – 2·5 (average 10 × 2), linear-oblong, obtuse.
Branchlets	Glabrous	Puberulous	Puberulous	Puberulous.
Inflorescence	On axillary peduncles, ± leafy, 4–13 clusters of 3–11 flowers	Terminal, on short arrested branchlets, 3–5 clusters of 1–3 flowers	Terminal, on short arrested branchlets, solitary, or in clusters of 2–5 flowers	Terminal, on short arrested branchlets, solitary.
Bracts	Forming involucres to clusters, lower leaflike	Forming involucres, lower leaflike but very small	Forming involucres, or all leaflike	Forming involucres.
Corolla-bud	5–6 mm.	3–4 mm.	2 mm.	2 mm.
Drupes	..	..	Solitary, 5 × 4, globose, cream-ground, ± blue-stained	Solitary, 6–5 × 4, oblong-globose, cream-ground, deeply blue-stained.

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NOTE.

Since this paper was written Dr. Cockayne's important general paper has appeared in *The New Phytologist*, vol. xxii, No. 3, p. 105, under the title "Hybridism in the New Zealand Flora." × *C. Cunninghamii* is accepted as an undoubted hybrid.

The lamented death of Mr. T. F. Cheeseman has deprived New Zealand of one of its most influential scientific leaders. Junior botanists will sorely miss one whose help and advice were always freely and generously given, and whose life-work remains to them as a sterling example of patient and devoted service to the cause of accuracy and truth, and an ever-present inspiration to honest endeavour.

EXPLANATION OF FIGURES.

FIG. 1.—Tracings of leaves, × ½: each representative of a particular plant. A, B, *C. robusta;* C, D, E, *C. propinqua;* remainder, *C. Cunninghamii* and "intermediate" forms.

FIG. 2.—Tracings of leaves, × ½: each representative of a particular plant. A, B, C, D, E, seedling *C. robusta;* F, G, H, K, seedling *C. propinqua;* P, Q, R, S —P S parents, Q R offspring; L, M, N, O, T, U, juvenile *C. Cunninghamii;* V, W, X, *C. robusta* var. *angustata;* Y, Z, *C. robusta* var. *parva;* remainder, seedlings from Mr. Atkinson's garden.

REPORT ON SAMOAN OBSERVATORY.

By C. COLERIDGE FARR, D.Sc., F.N.Z.Inst.

Published by direction of the New Zealand Honorary Board of Advice.

STAFF.

THE staff at the Observatory at present consists of Mr. A. Thomson, M.A., who is Acting-Director; Mr. C. J. Westland, F.R.A.S.; and four Samoan clerks—Vaeu'a, Ta'ase, Saaga, and Paniani; also two Chinese labourers.

SCIENTIFIC WORK.

The scientific activities at the Observatory may be divided for convenience into the following groups: Time-determination, magnetism, seismology, meteorology, atmospheric electricity, upper-air work, and tidal observations. The routine and detail of work in these various departments will be dealt with under the separate headings.

TIME.

For time observations a 2 in. transit instrument by Heyde is installed in a specially built hut, and observations are taken at least once a week,

the fortunate possession of an extremely reliable clock by Strasser and Rhode making observations more often than this, as a rule, unnecessary. The time so obtained is used for all ordinary observations, and frequently for the rating of ships' chronometers and for use in the Town of Apia itself. Time is transmitted by telephone every morning at 9, and for the noon gun twice a week. It is hoped later on, when the wireless set which is at present being erected at the Observatory is installed, to check also the longitude. Some small amount of work has already been done in this direction with the courtesy of the staff of the Apia wireless station, who in this and in every other respect have been at all times most willing to give their assistance in the Observatory work. In the event of any unforeseen accident happening to the clocks, there are four chronometers with which to carry on. There is also a contact clock with a mercury break which sends signals at intervals of every minute to the seismograph and at every hour to the magnetic-variation instruments.

TERRESTRIAL MAGNETISM.

Continuous records of the three magnetic elements—the horizontal intensity, declination, and vertical force—are kept at the Observatory, and it may be pointed out that it was in order to accomplish this object that the Observatory was originally established in 1902. For the purpose of the determination of the absolute values of the magnetic elements there are two absolute magnetometers—one (*a*) by Tesdorf, and another (*b*) on loan by the Carnegie Institution of Washington. An earth inductor for the determination of dip is also installed. The galvanometer which is used in connection with this instrument is lent by the same Institution. These absolute instruments have been compared with the standards at European and American observatories as occasion offered, and more especially in 1921, when the non-magnetic yacht "Carnegie," of the Carnegie Institution of Washington, visited Apia. This determination was thorough and satisfactory, and the factors then determined are those at present in use at the Observatory for reduction to international values. Absolute observations for the purpose of determining the base-line of the variation instruments are made in the case of the horizontal-force and declination variometers at least once a week, and for the vertical-force variometer, which has been giving a good deal of trouble, about four times a week. The magnetic-variation instruments are of the Eschenhagen type, and were made by Toepfer, of Potsdam. With the exception of the vertical-force instrument, the recording is quite satisfactory. The vertical-force variometer, however, has given, and is still giving, considerable trouble, and requires very frequent attention to keep it in working-order.

The variation instruments are installed in a double-walled concrete building, the sand used in its construction having been imported to ensure its being of a non-magnetic character. There is an air-space 20 in. wide between the walls.

The temperature inside the house is very constant, having an annual range of less than 3° C. Records of the variation of the magnetic elements have, it is believed, been maintained from 1902, though the first printed record at the Observatory seems to be 1905.

The records are, of course, photographic. These are completely reduced at the Observatory, due regard being paid to all international arrangements such as the well-known international quiet days. The

magnetic "character numbers" of all days is determined, and reports are forwarded every quarter to the proper international authorities at De Bilt, in Holland. A short *résumé* of the yearly magnetic results is also forwarded promptly at the close of every year to the Department of Terrestrial Magnetism, Carnegie Institution of Washington, and the year's general results are worked up at Apia, and published in due course under the auspices of the New Zealand Council.

Special observations were taken at the time of the two recent solar eclipses in 1922 and 1923, and the programme observed was in conformity with that requested by the Department of Terrestrial Magnetism and observed by other collaborating observatories throughout the world. The observations made since the New Zealand Government took over control of the Observatory in January, 1921, have been completely reduced by Mr. Westland, and the results for 1921 have been published.

The reduction work is well up to date. The results for the year 1923 will be ready for publication about July, 1924. Arrangements were made by Dr. Marsden and Dr. Angenheister, the former Director, for the reduction in Germany of the observations made from 1914 to the end of 1920. Some of this work, as the Council will know, has been done, and it is hoped that the rest will shortly be completed. The gap in publication which was caused by the war will thus be filled up. The publication of the yearly magnetic results from the present time will take place probably during the year following that in which they were obtained. The 1922 report is already in New Zealand, and the editor—Dr. Sommerville—has it in hand.

SEISMOLOGY.

There is installed at the Observatory a complete set of Wiechert seismographs, recording N.–S. and E.–W. components and the vertical component of the ground-movement. Though not the type of seismograph which might be installed to-day in an Observatory, yet the instruments at Apia are, on the whole, quite satisfactory, and give but little trouble. I have discussed, as I was requested to do, with Mr. Thomson and Mr. Westland the desirability of installing either a Milne-Shaw or Galitzin seismograph, and we are in agreement, I think, that, while either instrument would certainly be more "modern," there is so much that requires doing, and so many other instruments that are more urgently needed, it would be better for the present for things to remain as they are, keeping in mind, however, the fact that the present seismological equipment will probably require amplification in the not-distant future, and it will be necessary in a short time to consider another design. No new buildings will be required when it is thought desirable to obtain extra seismological equipment. The Wiechert pendulums are installed in a special room attached to the main office of the Observatory. With regard to the records, these are reduced promptly and sent out in accordance with the international arrangements. A detailed statement of earthquakes recorded is sent out every month to the President of the Seismological Committee at Oxford, England, as is customary with other observatories, and to Dr. Adams, the New Zealand Government Seismologist in Wellington. In case of a specially notable earthquake record, telegraphic notification is forwarded to New Zealand. Besides this, as the Council knows, a report of the seismological work done is being prepared semi-annually and printed locally, and distributed to seismological stations and libraries throughout the world. It has been prepared by Mr. Westland, and gives

the earthquakes from February to June, 1923. It is hoped to continue this every six months. This report, besides giving the details of particular earthquakes, gives also the epicentres of the earthquakes which occurred in the Pacific during the year 1921. This little publication may be regarded as an especially valuable activity of the Observatory, and I sincerely hope nothing will interfere with its prompt and regular appearance. It has also received the high commendation of the President of the Seismological Committee of the British Association, who says that he sincerely hopes that the seismological activities of this Observatory may be uninterrupted.

METEOROLOGY.

A regular programme of meteorological observations is carried out daily at the Apia Observatory. This involves observations at 9 o'clock every morning of the barometer, maximum and minimum thermometers (wet and dry bulb), rainfall, wind (direction and force), clouds, and visibility. In addition, self-recording instruments are in operation, giving records of sunshine, temperature-variation, changes in the barometric height, wind (direction and force), humidity, and rainfall. The barographs and thermographs date back to the time of the German occupation, and were made by Fuess, of Berlin. Owing to the exposed position of the Observatory and its nearness to the sea, considerable corrosion takes place in all metal-work, and those instruments which are necessarily exposed in all weathers have suffered with other metallic surfaces. In consequence of this corrosion the hygrograph had to be replaced by a new one, and this will be the fate of the other self-recording meteorological instruments shortly. A new thermograph is at present under order. The present barograph is showing the ravages of time, and will need replacement by a new one immediately.

The meteorological work at the Observatory is reduced and tabulated at once. Besides these observations, records of rainfall and sunshine are being obtained with the kindly help of twelve co-operating stations in Upolu, and it is hoped to increase this number as time and opportunity offers. In addition to these semi-local observations, records are also now being obtained from Pago Pago every month. The observer at Pago Pago is Lieutenant McLellan, the officer in charge of the Public Works Department and the Observatory, and the Council are indebted to him for his kindly assistance. Abstracts are made of these observations in Upolu, and the monthly summary of results is sent to the head of Crown Estates Department and the Public Works Department at Apia.

The Resident Commissioner of Savai'i, Mr. Bigg-Wither, is interesting himself in meteorological observations, and has made suggestions for increasing the number of Savai'i rainfall stations. So far, however, owing to the difficulty in obtaining rain-gauges, it is impossible to comply with his wishes. The matter is not being lost sight of, and it is hoped that arrangements will soon be completed for more stations in Savai'i.

A weekly statement, consisting of the daily values of maximum and minimum temperature, sunshine, and rainfall, is sent to the *Samoa Times* and published.

With regard to the general meteorology of the southern Pacific, the Apia Observatory acts as the clearing-house of meteorological information. Owing to the courteous and cordial co-operation of the officials of the Apia wireless station, information is now received daily from Suva, Tahiti.

Rarotonga, Norfolk Island, Nukualofa, and Vila, and at the end of each month the written statement of the meteorological condition at these places of each day of a month is received and tabulated and preserved at the Observatory. This record consists of daily observations, taken every morning, of the wind (direction and force), barometer (wet and dry bulb), cloudiness, rainfall, and condition of the sea. It is hoped to increase the number of stations from which reports are thus received.

In the event of a hurricane or severe storm developing in any region a special watch is kept upon it, and wireless information emanating from, and with the authority of, the Observatory is broadcasted for the information of any vessel which may be concerned. The Observatory sends out weather reports twice a day during the hurricane season (from November to April); and exercises, as far as possible, supervision over the work of the observers in other groups. Special mention should be made of the enthusiasm and cordial co-operation of Captain Twentyman at Suva.

ATMOSPHERIC ELECTRICITY.

Regular and systematic work is being done in this department. There are two self-recording Benndorf electrometers in operation. One of these is installed in a specially built concrete house in the lagoon, about three-quarters of the distance from the shore to the reef. The other instrument is erected in a wooden building in the Observatory grounds. There is also a third electrograph at the Observatory, but this instrument is incomplete owing to the absence of a driving-clock, which, however, has been ordered from the maker (Castagna) at Vienna, and should shortly arrive.

With regard to the two electrographs in operation, the one in the house upon the lagoon appears to be very suitably situated for this work. The only drawback to such a position is the possible influence of a rise or fall of tide. This, however, is provided against by a concrete platform, which is under the collector. The upper surface of this platform is about 7 ft. above the water at low tide and about 4 ft. at high water, and is 7 ft. below the Ionium collector. The effect of a rise and fall of tide is therefore screened by this platform, the surface dimensions of which are 8 ft. by 8 ft. 6 in. Under all tidal conditions it therefore forms an invariable equipotential surface of this size, 7 ft. below the collector. While this possible disadvantage may exist, the advantages of such a position are many: the south-east trade blows in over an uninterrupted sea surface for many hundreds of miles. There are no plants or grass which by their growth may alter the distributions of equipotential surfaces, and, moreover, there is no radio-active radiation except such as has penetrated through at least 10 in. of water. There is no dust, smoke, fog, or other of the various causes of trouble which are found associated with the sites of such instruments near big cities. Insulation difficulties, owing to the saltness and humidity of the air, do certainly occur, and instruments require careful and persistent watching. The house is visited daily in a boat over the lagoon either by Mr. Thomson or by Paniani, who has been specially trained for this work. It is believed that the records from the instrument will be unique. The electrograph-house upon the lagoon was erected this year, and observations were regularly commenced there last September.

With regard to the other electrograph, which is housed in the Observatory grounds, records have been obtained from it continuously since April, 1922.

The reduction factors for reducing the records of these two instruments to that of a plane surface are obtained by the Simpson method from absolute observations of the potential of a wire stretched upon a level area of considerable size, laid bare near the Observatory by the tide.

A few observations have also been made, particularly during last July and August, on the electrical conductivity of the atmosphere. Mr. Thomson hopes that in time he will be able to extend the atmospheric-electricity programme; and, indeed, much more might be done, given time, staff, and instruments. The electric condition of the atmosphere is a branch of meteorology which until recently has hardly received the attention which it undoubtedly demands. For example, instruments for counting the number of ions per cubic centimetre, and an instrument for measuring penetrating radiation, may be mentioned. The staff at the Observatory is keenly anxious to extend this work, and the instruments are not very costly.

UPPER-AIR WORK.

Balloons for the observation of the upper-air currents are sent up frequently—indeed, on almost every occasion when the sky seems to be clear enough to give some promise of a satisfactory flight. The regular programme of balloon observation was commenced on the 30th May, 1923, and up to the present date seventy-eight flights have been made. The longest time during which it has been possible to maintain a balloon in sight is 117 minutes. The balloons are inflated with hydrogen gas obtained in cylinders from Melbourne. They rise at a regular rate of 180 metres per minute. A balloon rising at this rate for 1 hour 57 minutes will attain a height of 21,150 metres, or 13·1 miles. It would seem necessary to place the fundamental assumption that the balloon rises with a constant velocity upon the soundest observational foundations, and work of this kind might be suitably carried out at Apia. There are two theodolites there which could be used for the purpose. One of these has been lent by the Canadian Meteorological Service through the courtesy of Mr. Patterson, who is in charge of the upper-air work of the Canadian Meteorological Bureau; the other was obtained from New Zealand. It is therefore proposed to make observations as opportunity offers with the view to checking this assumption in this latitude, and thus obtain also information as to the existence of vertical air-currents.

These balloon observations have already revealed certain definite results. The extreme variability in heights to which the south-east trade-winds extend, ranging up to about 8 kilometers (about 5 miles) as an upper limit, has been shown. The currents above the trade-winds are much more constant in velocity, and are usually in the opposite direction to that of the surface trade—that is to say, from the north-west. No indication has been found of currents at extreme altitudes parallel to the trade-winds at the surface.

The Observatory is indebted to the help of the United States Weather Bureau for the loan, for an indefinite time, of a balloon plotting-board, which greatly reduces the labour and time necessary for delineating the balloon's track and for computing the wind velocity and direction at different altitudes. The United States Weather Bureau has also sent an apparatus for filling the balloons, and a complete stock of reduction forms.

Immediately after the observation of any flight the results of such a flight are reduced, and the N.–S. and N.–W. components are obtained.

On the days chosen by the Commission International pour l'Exploration de l' haute Atmosphere, Christiania, special attention is paid to balloon flights, and if conditions at all warrant it two balloons are sent up. Results of these flights are at once sent to the headquarters of the International Commission at Christiania.

It is desirable that complete and regular supplies both of hydrogen and of balloons should be arranged. Of two cylinders of hydrogen recently received from Melbourne, one was found to be empty when it was first opened, two months after arrival. The hydrogen is obtained from Melbourne. It might be well if the Board made inquiries in New Zealand as to the regular supply of this gas from there, in order to ensure regular supplies. The Observatory possesses four cylinders, of which, as a rule, two are away in Melbourne being filled while the other two are in use at the Observatory. A fifth cylinder, as a stand-by in case of such an occurrence happening again, would be of value. The balloons have been obtained from the United States Rubber Company, and are identical with those used by the United States Weather Bureau. The arrangements made with the Bureau were carried on through the Carnegie Institution of Washington. Since the present system has been arranged the supply has been regular and satisfactory, and it is hoped that the arrangements made will now work smoothly.

The uninterrupted expanse of sea which surrounds the Observatory, and the paucity of observations of balloon flights in the Southern Hemisphere, give the flights at Apia a special value, which is quite recognized by the authorities in Europe and America in their correspondence with the Observatory.

TIDAL WORK.

For many years tidal observations have been taken by means of a tide-gauge, installed at the Customs Wharf, in the Town of Apia. Apia is amongst the list of eighty-two standard ports of which complete tidal data is given in the volume of tide-tables published by the United States Department of Commerce at Washington. The supervision of this tide-gauge has quite properly been undertaken by the Observatory authorities. Tidal results are important, not only for navigation purposes, but also in connection with tidal waves occuring in the Pacific.

It may be mentioned that the Chilian earthquake which occurred on the 10th November, 1922, produced a sea-wave at Apia having a range of 20 in., a time of ebb and flow of twenty-seven minutes, and the oscillation continued for three days. Such results are frequently recorded at Apia.

In order to ascertain if there is any slow land-movement taking place in the Island of Upolu, the Public Works Department, while under the direction of Mr. Tyndall, established a very solid bench-mark in front of the Public Works Office, and an elaborate series of levels has been taken between this and the tide-gauge. The tide-gauge at Apia is old and corroded, and a new one will have to be installed immediately. For the purposes of observation of atmospheric electric potential at the reef electrograph, tidal heights are also required; and, as the Apia tide-gauge has practically worn out with corrosion and age, it was decided to erect any new gauge which might be obtained at the electrograph-house in the lagoon, which is nearer to the Observatory and is visited regularly every day. The Customhouse is a mile away, and the reef house is about one-third of a mile. The suggestion met with the approval of the Public Works Department, which has installed the bench-mark. Owing to this connection with potential gradient observations, the Department of Terrestrial Magnetism,

Carnegie Institution of Washington, undertook to supply a tide-gauge of the most approved pattern. In a letter of the 1st June, 1923, which Dr. L. A. Bauer wrote to Colonel Jones, the Director of the United States Coast and Goedetic Survey at Washington, permission was asked to obtain from Messrs. Bausch and Lomb a tide-gauge of the pattern and design used by the United States Coast and Geodetic Survey which embraces all the most modern improvements. So far the expected tide-gauge has not reached Apia, although it may by any mail. It has been expected at any time since September or October. This accounts for the fact that tidal observations at Apia have not been made for the past three or four months. No time will be lost, on the arrival of a new gauge, in installing it, and a series of levels will immediately be taken to the already-mentioned bench-mark.

It would be well if bench-marks and a tide-gauge of perhaps a cheaper pattern could be erected on the Island of Savai'i. This island is inhabited by about twelve thousand people, and has been subject to many volcanic eruptions. The last one extended over the years 1908–11. The volcano Matavanu is at present not active, but it cannot be foretold when it may become so. Observations of earth-movement, especially at Fagamalo, the seat of the Resident Commissioner, might perhaps give some indication of pending activities. Possibly a comparatively cheap tide-gauge which would determine the height of a bench-mark above the mean sea-level might be installed there.

The Observatory would be glad to supervise the operation if the tide-gauge is obtained. It may be mentioned that enormous masses of lava were thrown out of the volcano Matavanu during the last eruption ending in 1911, and any slow tilting of the land would thus be made evident.

BUILDINGS.

During the war, and practically until the New Zealand Government took over the administration of Samoa three years ago, the Observatory buildings were evidently considerably neglected, and though some money (about £250) has been spent upon them during 1923 it will be necessary to spend more. Iron and woodwork which are not constantly watched very soon become corroded and rotten in the tropics. This decay is very evident in some of the Observatory buildings. In some cases the galvanized iron of the roof of the buildings has been corroded right through, and the woodwork in many places is decayed and requires immediate attention.

I have gone into the matter of repairs most urgently necessary, with Mr. Phillips, the chief carpenter of the Crown Estates, and he has given me an estimate of the cost of repairs. This estimate, however, intentionally makes no provision for the cost of supervision and contingencies. Mr. Cowley, general manager of Crown Estates, tells me that perhaps it would be right to add an amount not exceeding 30 per cent. for these items. This will put the cost of the work contemplated at about £160, and will make the Observatory a much more presentable place and more in keeping with the character of the work which is done there than it is at present, and render it habitable. More, however, will be needed to be spent on the buildings in the near future. The smaller house (which is occupied by Mr. Thomson) was built, I understand, as a temporary residence for an engineer, during the German times. It is built with its floor on the ground, and it is impossible to say what is the condition of the floor-joists. The woodwork of the floor itself seems

to be in fairly good order, but there are signs of weakness in some of the timbers underneath. It might be better if this building could be raised to allow the air to pass freely beneath it, so that the under woodwork might be open to inspection. We are obtaining an estimate of the cost of this alteration, though at the time of writing it has not come to hand.

The Mulinu'u Peninsula, on the end of which the Observatory is situated, is sacred to Samoans on account of its history and of its being the burial-place of many of the great Samoan Kings. For example, two of the greatest Samoan rulers—Malietoa Laupopa and Malietoa Fa'alata—are buried in the Observatory grounds, not more than ten yards from the larger residence. It is only in consequence of the nature of the work done at the Observatory that the Samoan people do not take exception to its existence there, and it is not seemly on this account alone, if on no other, that the Observatory buildings and grounds should be maintained in anything but the best repair and order, which is not the case at present. It is much to be hoped that no parsimonious policy will be adopted, for I believe that it will be in the best interests both of scientific advancement and of our relations with the native race for these grounds and buildings to be an object-lesson rather than an eyesore. It is no one's fault that the buildings are in the condition they are at present: it is purely the result of the war and of the uncertainty of the time through which we have passed. They should now be put in good order, and then, with a relatively small expense, they can be maintained so.

RECOMMENDATIONS.

(1.) *Scientific.*—I recommend that the following instruments be obtained:—

(*a.*) An additional Z (vertical force) magnetic variometer.
(*b.*) A new barograph.
(*c.*) A micro-barograph.
(*d.*) An evaporation-gauge.

In addition to this gauge it will be necessary to construct a small concrete evaporation-tank. This particular instrument has a bearing on copra-drying operations.

(*e.*) One pair solar radiation thermometers as recommended by the Royal Meteorological Society of England.
(*f.*) A supply of small sundries such as every Observatory needs and which is at present lacking at the Apia Observatory. This will include spare thermometers, evaporation-dishes, &c.
(*g.*) Two chucks and a supply of high-speed steel and tool-holders for two small, but good, lathes which the Observatory has and which for want of these are useless.
(*h.*) General supply of carpenters' tools.

I recommend that the investigation of ocean currents in this part of the South Pacific be undertaken by the Observatory. For this purpose it will only be necessary to have a supply of current-papers printed in the various Polynesian languages (and, say, in French and English) for enclosing in bottles. Such papers would contain a request in these languages that the finder would return the paper to the Apia Geophysical Observatory, giving the date and place where it was found. The Acting-Director has made it his practice to call on the captains of ships visiting Apia, and he anticipates no difficulty whatever in securing the co-operation of shipmasters in this oceanographical work.

It would simplify the financial arrangements of the Observatory if the accounts of the Observatory were kept mainly in Apia rather than in Wellington, and that a sum of money should be transferred to the Samoan Treasury at Apia as an Observatory credit, from which the Observatory might draw, rather than having, as at present, to send these vouchers through the Administration to Wellington. The Acting-Director is at this moment ignorant of the financial position and of the credit balance in hand, reference having been necessary to Wellington before such information could be obtained. This is not desirable.

It would be necessary, with the appointment of a permanent Director, to consider the financial position thoroughly, and it will be wise and helpful to those Departments concerned in Apia to consider the points mentioned.

The Observatory, since the year 1921 until now, has been supported by joint contributions from the Carnegie Institution of Washington, the British Admiralty, and the New Zealand Government, and of these the Carnegie Institution of Washington has so far borne the largest share. It now desires to be relieved of some of this burden—a burden which it voluntarily undertook in the interests of science and in order to tide this important geophysical institution over a difficult period.

There is a good printing-office, owned by the London Missionary Society, employing about thirty hands, at Malua, a few miles from Apia. It would be a convenience for the Observatory if small printing could be done by them rather than having it sent to New Zealand. No doubt the Malua printing-office would be glad to give an estimate of the cost of this work. The Malua printing-office could not deal with such documents as the magnetic reports, which involves large numbers of figures, as it has not enough numerical type; but for the smaller things, such as the semi-annual seismological reports and printing of that nature, this arrangement would be a convenience and an easy possibility.

It is desirable that a close connection be maintained between the Apia Observatory and similar institutions. The Acting-Director has opened up correspondence with the Hong Kong, Batavia, and Mauritius Observatories. Owing to the fact that the Acting-Director is at this present moment an officer of the Carnegie Institution of Washington, the most friendly and cordial relations exist between himself and the American geophysicists. This relationship is in every way good, and it seems desirable to cultivate a similar cordial feeling between the Observatories and scientific men in British countries.

CONCLUSION.

I had not realized until I visited Apia, nor do I think the members of the Honorary Board of Advice are aware, how much the Observatory owes to the liberal and far-reaching policy of the Department of Terrestrial Magnetism of the Carnegie Institute of Washington. Not only has this institution paid the salary of Mr. A. Thomson and a native assistant, but it has supplied many hundreds of pounds' worth of instruments, extending from a balloon plotting-board to a tide-gauge.

I wish, in conclusion, to express my appreciation of the keenness I found among the members of the Observatory staff, and to thank those other departments of the Administration of Western Samoa who co-operate with the Observatory for the courteous help which they have always given to that institution, and which they so markedly extended to myself during my visit.

SECOND PAN-PACIFIC SCIENCE CONGRESS, AUSTRALIA, 1923.

ORGANIZATION OF THE CONGRESS.

By Dr. J. ALLAN THOMSON.

THREE years ago, in August, 1920, a small meeting of scientists, gathered from various countries around the Pacific, was held in Honolulu, under the title of the Pan-Pacific Science Congress. Japan, the Philippines, Australia, New Zealand, and Canada were represented by quite small delegations, the majority of the members coming from Hawaii and the United States, while the great British, French, and Dutch island possessions in the Pacific were unrepresented. Little interest in the scientific world was taken in the Congress, there being no reports even of its occurrence in the British scientific news journals. Nevertheless the success of the Congress was so great, its published results so fruitful in the realms of Pacific anthropology and geology in particular, and the enthusiasm created in those fortunate enough to attend so infective, that the second Pan-Pacific Science Congress recently held in Australia was one of the most representative, largest, and most successful gatherings of the kind that the world has yet known.

The first Congress owed its inception to the convergence of two diverse movements. The idea of a Pan-Pacific Science Congress was discussed in Australia in 1914, at the time of the meetings of the British Association, because at that time there was a small American Congress sitting in Honolulu. Interest in Pacific scientific problems had been steadily growing in America, and a symposium of papers on the subject had been published and plans for exploration discussed. Meanwhile, in Honolulu, the Pan-Pacific Union, which is a non-scientific organization devoted to the interests of peace and general co-operation amongst the countries bordering the Pacific, had been endeavouring to promote its objects by planning a series of Pan-Pacific Congresses. Professor H. E. Gregory, of Yale University, who was then acting as Director of the Bishop Museum at Honolulu, was invited to become chairman of the first Congress, and he consented on the understanding that it should be a purely scientific one. The first Pan-Pacific Science Congress was held under the auspices of the Pan-Pacific Union, with official recognition from the Governments of the United States, the Territory of Hawaii, and New Zealand. To the Pan-Pacific Union and its active director, Mr. Alexander Hume Ford, Pacific science is deeply indebted for the opportunity thus afforded to inaugurate the Pan-Pacific Science Congresses. The first Congress was, however, quite an autonomous body, and set up a "hold-over" committee, consisting of one representative from each of the countries represented, to arrange for future Congresses. The reports of the first Congress were published through the generosity of the Bishop Museum of Honolulu.

Since that date Mr. Ford and the Pan-Pacific Union have promoted other Pan-Pacific Congresses at Honolulu on such subjects as education, trade, and conservation, but these have no connection with the Science

Congresses, the organization of which has now devolved upon the National Research Councils of the lands bordering the Pacific, or bodies occupying in their countries a similar position, such as the New Zealand Institute. For finance future Congresses are so far dependent mainly on the Governments of the countries issuing the invitation, and it is significant of the growing importance attached by these Governments to the encouragement of science that, whereas the Commonwealth Government made the second Congress possible by a grant of £5,000, the Japanese Government have promised £23,000 for the third Congress.

It was hoped that it would be possible to hold the second Congress in New Zealand in 1923, but the financial "slump" in 1921 found the New Zealand Government undisposed to make the necessary financial provision. Thanks very largely to the unflagging enthusiasm of the Australian member of the "hold-over" committee, Mr. E. C. Andrews, the Commonwealth Government and the State Governments of New South Wales and Victoria stepped into the breach and voted sums which made it possible to hold the second Congress in Australia. The invitations were issued and the arrangements for the Congress undertaken by the Australian National Research Council, and its President, Sir David Orme Masson, presided over the Melbourne meeting from 11th–21st August, and in his absence owing to ill health the Vice-President, Sir Edgeworth David, presided over the Sydney meeting, 22nd August – 3rd September.

The various Governments of Pacific countries, and the chief scientific societies and institutions, were invited to send delegates, and besides those representing Australian States there were about eighty overseas delegates present, representing the following countries: Great Britain, United States, Canada, Alaska, Japan, Formosa, Hong Kong, Burma, Malay States, Holland and the Dutch East Indies, Philippines, Papua, Hawaii, Tahiti, Fiji, New Zealand, India, and South Africa. Besides official delegates, an opportunity was given to members of the public to join the Congress and attend the meetings. In Melbourne two hundred local members and in Sydney five hundred were enrolled.

The New Zealand delegation consisted of Messrs. P. G. Morgan, A. H. Cockayne, Dr. P. Buck, and Dr. Armstrong (of Samoa), representing the Government; Professor H. B. Kirk and Drs. P. Marshall and J. A. Thomson, representing the New Zealand Institute; Drs. T. H. Easterfield and R. J. Tillyard, representing the Cawthron Institute; Professor J. Macmillan Brown, representing the University of New Zealand; Professor R. Speight, representing Canterbury College; and Professor W. N. Benson and Mr. H. D. Skinner, representing Otago University. Dr. Buck and Mr. Skinner were also the delegates from the Polynesian Society. The overseas delegates were throughout the guests of Australia, and received unbounded hospitality and the freest opportunities of travelling throughout Australia both before and after the Congress.

The Congress was divided into twelve sections, as follows: Agriculture, Anthropology and Ethnology, Botany, Entomology, Forestry, Geodesy and Geophysics, Geography and Oceanography, Geology, Hygiene, Pacific Radiotelegraphy, Veterinary Science, and Zoology. Except for the inaugural meeting and a closing general meeting to discuss resolutions, all the meetings in Melbourne were sectional meetings; in Sydney, besides the sectional meetings, there were in addition several general meetings of the whole Congress devoted to general topics, but the programmes of many sections

were so full that their meetings went on concurrently with the general meetings. A resolution was proposed adding Chemistry to the number of the sections, but it met with opposition on the ground that the Congress was already too much broken up into sections, and was defeated, the sectional organization of the next Congress being left entirely in the hands of the inviting country (the National Research Council of Japan). The excursions were also to some extent run on sectional lines, so that there was not the same opportunity as at Honolulu of meeting men of all branches of science; but this was inevitable considering the size of the Congress and the immense programme of work carried out by the sections.

For those fortunate enough to attend such a Congress the justification for the time and expenditure involved is the opportunity of meeting other workers in science and discussing problems with them. The widening of horizons, the inspiration, and the encouragement to persevere in what might otherwise be a "lonely furrow" are very real acquisitions, and help greatly to improve the efficiency of the scientist whether he be a Government officer or a University teacher; from this point of view alone the public expenditure of money on such Congresses is justified. But the Pan-Pacific Science Congress effected a great deal more than this. The first Congress published reports of lasting value to Pacific science, particularly in the domains of anthropology, geology, and geophysics and vulcanology. The second Congress covered a much wider field, and it is safe to predict that the reports will embrace papers in almost every science which workers in Pacific lands will be unable to neglect. No doubt these papers would have been published sooner or later in some form or other, but their collection in symposia treating of the whole Pacific region will greatly facilitate reference. The reports will constitute veritable text-books on many subjects—such, *e.g.*, as the Tertiary geology of the Pacific region—text-books that would otherwise never have been compiled. But, further, the publicity given to the proceedings of the Congress in Australia, both by public lectures and in the Press, will immensely assist the task of those who are fighting for an adequate recognition and use of scientific knowledge in public affairs. Other countries, such as New Zealand, must take their turn in becoming hosts for future Congresses to enjoy this advantage. Finally, perhaps the most important aspect of the Congresses, as emphasized below by Professor Benson, is the increase in mutual understanding and good will that attends all such international gatherings.

The Japanese Government and the Japanese National Research Council have extended a cordial invitation for the Third Pan-Pacific Science Congress to be held in 1926 in Japan, and this invitation has been accepted.

IMPRESSIONS OF THE CONGRESS.

By Professor W. N. BENSON.

The opening speech of welcome was given by the Commonwealth Governor-General, and read by the Prime Minister, Mr. Bruce, who emphasized both objects of the Congress, welcoming the scientific delegates also as ambassadors of good will. Sir David Orme Masson, President of the Australian National Research Council, gave the inaugural address in

Melbourne, emphasizing the importance of the study of Nature's laws in order to learn how to turn them to the benefit of mankind. Professor Sir Edgeworth David, in seconding Sir Orme Masson's welcome to the delegates, pointed out that the members of the Congress represented four hundred million people around the shores of the Pacific whose hope was to make the Pacific truly pacific.

Professor Count Sakurai, head of the Japanese delegation to the Pan-Pacific Congress, Vice-President of the National Research Council of Japan, and representative scientific member of the Japanese House of Peers, speaking most beautiful English, said, in acknowledging the welcome: "Never before has Japan sent so large a delegation of scientific men to any Congress either in America or Europe. That fact shows how deeply interested Japan is in the work of the Congress, and also the strong brotherly feelings her scientists have towards their Australian colleagues. I hope that the Congress will tend to dispel misunderstandings, if there are any, and will promote the well-being of the peoples of our respective countries, and that our nations will thus learn to respect and trust one another. The aim of science is the pursuit of truth and its application to human welfare, and to scientists united in that common aim all thought of enmity, whether arising from differences of race or of religion, is absolutely hideous."

The delegates were given the hospitality of the colleges at the Melbourne University as well as that of many private citizens; and in particular the group of twelve New Zealand representatives shared with the Japanese representatives the hospitality of Ormond Presbyterian College. Count Sakurai was a delightful personality, and they all became particularly fond of him.

The work of the Agricultural Section in Melbourne was under the chairmanship of Professor Easterfield, Director of the Cawthron Institute for Agricultural Research in Nelson, and so much interest was taken in his account of the work of that Institute that he was induced to go to Western Australia to confer with those who are endeavouring to found a similar institution there. The Agricultural Section met with the geographers, and there was careful discussion of the effect of climate control on human efficiency and productivity of crops. The possibility of breeding new local varieties of farm-plants and farm-animals that would be more suited to the local conditions of any place than any at present existing and the problem of irrigation and the extent to which it could increase the productive area of a country were also closely considered. The need for close investigation of meteorology was discussed, and it was especially pointed out how great was the need for exact methods of seasonal forecasting for a long time ahead, so that proper provision might be made for the future in regard to stocking and the planting of crops. No exact methods for doing this are at present in our possession, but the problem does not seem to be insoluble. Indeed, it is one calling for investigation on a very extensive scale. It is being partially attempted in India in the forecasting of the monsoons, but much remains to be done. One here realizes the need for geographers that information in regard to New Zealand weather should be published very much more freely. This is a matter in which we are far behind the methods of the Australian Commonwealth Meteorological Bureau, which admittedly is in the very forefront of progress on these lines.

Then, too, there were the questions of the need for soil surveys, both regional and in detail; the effect of various fertilizers; the study of the inheritance of the tendency of various plant stocks to succumb to disease; methods of improving plant-breeding, especially in regard to wheat, maize, and fruits. Of great interest was the demonstration of the American work on the control of wheat-rust by Professor Stakman, the world's authority on the problem. Then came also consideration of plant quarantine to eliminate the possibility of the introduction of diseases. Much interest centred in the discussion, taken together with the very active Entomological Section, on the work of the sugar-planters in Hawaii and elsewhere in getting proper control of insect pests. Improvements in the growth of rice and cotton were also dealt with, and the very advanced methods of Japan created much interest. Professor Easterfield discussed the problem of the growing of New Zealand flax; and then, too, the best methods of agricultural education were considered. Here again the methods of Japan, among others, were seen to be very good. She has three universities, ten agricultural colleges, and several experimental stations fostering scientific agriculture.

The Veterinary Section meeting with the agriculturists, debated at considerable length the laws of genetics in relation to sheep-breeding. The methods of control of cattle-tick, the blow-fly pest, and quarantine regulations were also considered.

Forestry attracted considerable attention. Delegates were glad to hear accounts of American work in methods of education in forestry, and a strong recommendation was carried that a laboratory of forest products should be instituted. The need of reafforestation and the best methods of promoting it were considered. Of surprising interest was the account of the magnificent work of the Japanese in Formosa in combating wood-borer by the white ant, and so on. A subject of such importance in the tropics caused considerable discussion.

The Hygiene Section was a very busy one. With the entomologists it discussed the function of insects in the spread and in the control of disease, especially in connection with tropical diseases. Other subjects before it were the best methods of control of plague, yellow fever, and leprosy; the ill effects of measles and possibilities of preventing its spread among the native population in many of the Pacific regions where it has a deadly effect; the health of miners; liability to hookworm disease; and the effects of dusty air. The hereditary transmission of cancer was also studied, illustrated by the detailed investigations of an American laboratory upon forty thousand mice belonging to thirty generations. These investigations proved that the transmission of the disease followed the laws of Mendel in that it would remain dormant in a generation which was of disease-resisting type, but would reappear again if such individuals were mated with less resistant stock.

The importance of establishing zoological and botanical sanctuaries for the preservation and the study of the fauna and flora was urged by the Zoological and Botanical Sections, and the former specially considered the possibility of restocking the fisheries of pearl-shells, whales, and seals, which have become depleted through being exploited by unscientific methods.

The geologists and geographers considered very many topics. They discussed particularly the unity of the Pacific as a grand geographical feature whose framework had been determined by earth-folds resulting

from one common origin, and whose crust-movement had in turn affected the geography, the climate, the economic conditions, and the plant and animal conditions all around.

The geologists especially considered the evidence of the origin and value of the ore deposits about the Pacific, and the oil and artesian-water resources, and the age and origin of the more important coal-measures, and, perhaps of more technical interest, the younger rocks around the Pacific. The geological architecture of the several lands, the present topographical features and their significance, the effects of the Ice Ages and igneous activity, and the nature and origin and distribution of coral reefs and conditions of marine life thereon, and its possible economic utility, were among the varied problems that came before this section. The status of Geological Survey Departments all round the Pacific was considered, and here, too, New Zealand delegates had to deplore the small opportunities afforded to our own Geological Survey for carrying on its work to the standard set up by such advanced countries as America or even Japan. The American Geological Survey recognizes that the production of an accurate topographical map showing quantitatively relief as well as other features is a necessary basis for any geological work, and even in the wilds of Alaska it produces better maps as a basis on which geologists may work than exist in any one of our mineral fields. A similar extremely advanced state of mapping was made very clear by the exhibits shown by the topographical survey of Java and Sumatra. Here, too, the mapping of the country is of a very thorough nature. All the features of habitation, economic resources, industries, vegetation, rainfall, are all charted in detail, and the Congress stressed the extreme need of other countries round the Pacific undertaking work of like nature as being essential to the systematic assumption of control of future progress of the country on all agricultural and mining lines.

More detailed surveys involving the most exact determination of the positions of latitude and longitude with a most rigid accuracy were also very badly needed in many of the countries around the Pacific. Work that was in progress before the war in New South Wales on these modern lines had been suspended, and its continuation was much desired.

The hydrographic work of studying the tides, and so on, by Japan was again of an extremely advanced character, forming a model for many others. The study of volcanic action in Java was made most vivid by a wonderful series of aeroplane photographs taken when flying over the active volcanoes. Most striking of all was Professor Omori's account of the work of his department in the seismological and vulcanological survey of Japan. He is perhaps the leading authority on this subject in the world, and has made a profound study also of the best methods of construction of buildings so as to resist earthquake shocks. He is able now to foretell with a certain degree of accuracy the imminence of an eruption or earthquake. The growing stresses in the earth are indicated by its quiverings, and on at least one occasion a great benefit resulted from Professor Omori's knowledge. He warned the Japanese Government that a certain volcanic island, Sakura Jima, was in a very dangerous state. The police removed the thirty thousand inhabitants from that island to the mainland, fifteen miles distant, and within three days' time the island almost exploded and nearly every building on it was totally wrecked. He had realized recently that earth-tensions were accumulating in Japan. These might have been dissipated

in a series of small shocks, but it was not expected, so Professor Omori told the Congress, that the crisis would occur so soon or that it would be so vast and catastrophic as had actually been the case. My last glimpse of Professor Omori, as he was leaving Sydney, was of him urging on New Zealand delegates the importance of detailed investigation of this character in their country. He pointed out that we, too, lie on the margin of the Pacific, and in some measure—fortunately to nothing like the same extent—we are liable to seismic and volcanic catastrophes. One remembered that very little indeed has been done in New Zealand in the survey of its volcanic regions since first they were visited by the Austrian Hochstetter seventy years ago, and that at the present time the installation of modern seismic instruments is far from complete. Certainly a movement to rectify this was in contemplation just before the recent financial stringency, and it is hoped that it will be taken up again as soon as possible.

While one was forced to realize the backward state of certain other sciences in New Zealand, it was gratifying to see the high place she took in anthropology. The addresses of Dr. Macmillan Brown on Easter Island and the account of Maori culture by Dr. Peter Buck were widely approved, and the activities of Otago University, in which it has instituted the only course of teaching in the subject in Australasia, is leading the way to similar academic interest in the subject in Australia which is now in contemplation. Much interest was also taken in the films of old Maori life obtained by the Dominion Museum ethnographical expeditions, and similar action was urged on the Commonwealth Government.

A pathetic interest attaches to the meeting of the Congress in Sydney, at which the inaugural address was given by the late Sir Walter Davidson, whose death happened shortly after the Congress. On all sides one heard the expression that this was the finest address the Governor had ever delivered. He, too, joined in directing attention to the vast international significance of these meetings. The closing sentences of that address, which proved to be the last public utterance of that distinguished statesman, were : "And, at the end, while we wonder that science and art and good will, advancing hand-in-hand, can invoke blessings, spiritual, mental, and material, on our assembled nations, yet always in the deep recesses of our hearts we wonder—nay, we hope and, indeed, we do believe that meetings such as ours will exorcise the demons of jealousy and unrest, and lay them in a limbo with the brutalities and follies of the past. Nationhood—the pride of race—is a glory only so long as its inspiration is actuated by peace on earth and good will among men."

At the conclusion of the Congress several executive meetings were held to draw together the recommendations of the various sections for the promotion of further scientific work, and these were presented for consideration at a final meeting. At that meeting also the delegates expressed their deep sympathy with the Japanese delegates, who on the very day that their great calamity was announced put forward on behalf of their Government an exceedingly generous invitation for the next session of the Congress to be held in Japan in 1926 an invitation that was gratefully accepted. The Australian National Research Council was appointed as the executive body to arrange for the publication of the proceedings of the Congress, to shape finally and carry out all the recommendations that had been passed and place them before the respective Governments or other authorities to whom they were addressed. Further, it was to act as a central

executive, with branch executives such as the New Zealand Institute or representative research councils in other countries to keep in touch with the scientific needs and to prepare material for consideration before the next Congress, when their colleagues of the Japanese Research Council would then take charge of the proceedings. Thus the work of the Congress does not cease with its last meeting, but goes continuously forward.

From every point of view the Congress was a wonderful success. Its scientific achievements were great, the stimulus it has given to further work still greater, but greatest of all has been its international significance. Our American visitors were deeply impressed by the spontaneous sympathy expressed by the memorial service for President Harding held in Sydney Cathedral a few days after they arrived, and the Japanese with the hearty acceptance of the friendly hand they put forward, an impression immeasurably deepened by the practical sympathy in calamity given by Australia to the nation whose representatives she had learned to esteem so highly. These two links, coupled with that forged by America when with characteristic generosity she leaped to Japan's assistance, will have drawn around the Pacific the threefold band of human sympathy that is not easily broken.

The Congress was closed by Professor Sir Edgeworth David with the following words: "This concludes this session, the historic session, as we hope it will be recognized in after-years, of this Pan-Pacific Science Congress. We are all brought closer and closer together here by our common studies. We are nearer than ever we were to one another's hearts. We feel that we have met not only to discuss problems of the great Pacific, but to realize that we are for ever brother mariners on that greater and deeper sea of Science, of which none can as yet descry the shores. In this quest together of the Infinite is our help, our hope, and inspiration. Ladies and gentlemen, this Congress in our Commonwealth now is ended. It lives again in Japan."

WORK OF THE SECTION OF ANTHROPOLOGY AND ETHNOLOGY.

By H. D. SKINNER.

Under the vigorous chairmanship of Dr. Alfred Haddon, F.R.S., Reader in Ethnology at Cambridge, a long programme of papers and discussions was worked through. Professor Grafton Elliot Smith's theory that all civilization can be traced back to Egypt—a theory which has aroused much discussion, some of it very heated, in recent years—was bound to come under consideration. It was fortunate, therefore, that we had with us Mr. W. J. Perry, Reader in Cultural Ethnology in the University of London, who is Elliot Smith's accredited champion, and whose book, *The Children of the Sun*, has just appeared. There appeared to be a general consensus of feeling that Egyptian influence has deeply affected the culture of southern Asia and the Pacific, but Mr. Perry's book was vigorously criticized by several field workers. A wide divergence of view as to the most fruitful method of attacking ethnological problems became evident early in the Congress. On one side were the geographers, headed by Professor Griffith Taylor, who hold that man is very largely the product of his environment. This doctrine of the relative passivity of

mankind was trenchantly assailed by Perry, who holds the "dynamic" view—namely, that man imposes his will on his surroundings, and that he has gone into inhospitable regions not because forced there, but because there was some sufficient motive, such as the search for gold, to lead him there. These two opposed parties have this in common, that each believes it has discovered general principles which can henceforth be applied to explain the culture of any and every people. The lack of success which has thus far attended the efforts of both parties to apply their principles justifies a conservative attitude on the part of non-partisans.

The organization of anthropological work in the Pacific was discussed, and Dr. Buck, who brought a message of greeting to the Congress from the representatives of the Maori race, was able to announce that the Maoris had set up an Ethnological Research Committee, with funds amounting to £1,000 a year for the next five years, which would aid financially any approved researches into the Pacific, and particularly Maori, ethnology. This announcement was greeted with great enthusiasm. At the close of the Sydney session Dr. Haddon was able to announce that the Commonwealth Government had decided to establish a Chair of Cultural Ethnology in the University of Sydney. Judge Murray, Administrator of Papua, stated that leave would be granted in rotation to all administrative officers in Papua to receive instruction in ethnology at Sydney.

In addition to members already mentioned, the Anthropology Section included Professor Hunter, who holds the Chair of Anatomy at Sydney, and is the most youthful professor in Australasia. It is he who recently described the Piltdown skull before the international congress of anatomists at Leyden. He is very keen on anthropological work, and Mr. E. Gulberg is carrying out an anthropological survey of Sydney University students under his supervision. Dr. Buck was extremely popular, and his public lecture was crowded to the doors. Of greater interest to members of the section was his account of his important researches into the technique of Maori textiles.

RESOLUTIONS ADOPTED BY THE CONGRESS.

Among the numerous resolutions passed by the Congress the following are of more particular interest to New Zealand :—

ANTHROPOLOGY AND ETHNOLOGY.

(6.) *Areas of Research.*—The Congress is generally agreed that it is desirable for practical purposes that the investigation of various areas in Oceania should be undertaken as a whole by definite bodies.

The Pacific region may be divided into four main areas—(i) Australia, (ii) New Guinea and Melanesia, (iii) Polynesia, (iv) Micronesia.

It is suggested—(i) That Australian ethnology be the special concern of Australia; (ii) that Australia should more particularly investigate Papua, the Mandated Territory of New Guinea, and Melanesia, but Great Britain and France should assist in this work; (iii) that the investigation of the Maoris be the especial province of New Zealand; the rest of

Polynesia may be recognized as pre-eminently the field for American research, with the co-operation of France and New Zealand; (iv) that the study of Micronesia be the particular province of Japan and America.

(8.) The following resolution was passed by the section, to be forwarded to the parliamentary representatives of the Maori race: "That the members of the Anthropological and Ethnological Section of the Pan-Pacific Science Congress receive with pleasure the greetings of their Maori colleagues, and express their appreciation of the practical steps taken by the parliamentary representatives of the Maori race in founding an Ethnological Research Fund. They convey to the representatives and the Maori people they represent their greetings and best wishes for support and success in the work they have begun. They are gratified that one of the objects of the Congress is receiving magnificent support from one of the native races of the Pacific."

(9.) That the Commonwealth Government be asked to take steps to obtain complete cinematograph records of the various industries and arts of the Australian aborigines, on similar lines to the admirable work being carried on by the Dominion Government of New Zealand.

BOTANY.

(1.) It seems desirable that a complete botanical survey be made of Macquarie Island, in order to obtain records of plant distribution and migration of Antarctic flora.

GEODESY AND GEOPHYSICS.

(9.) This Congress recommends the establishment of more seismographs of high sensitivity in the Pacific region.

PACIFIC RADIOTELEGRAPHY.

4. That it be a suggestion to the Governments of the United States, Japan, Dutch East Indies, Australia, France, and New Zealand to establish a daily mean-time signal, and that this signal be transmitted at 8 p.m., local standard time, from Funabashi, Tahiti, Cavite, Bandung, Perth, Adelaide, and Melbourne, and 9 p.m. from Sydney and Wellington. It is suggested that the signal consist of (*a*) a dash between the second 0–2, 10–11, 20–21, 30–31, 40–41, and 50–51; (*b*) a dot at every other second, to be continued without breaks for 5 minutes, starting with a long dash at 55 min. 0s.–2s. and finishing with the long dash at 0 min. 0s.–2s.

GEOLOGY.

(8.) That, in view of the importance of meteorological and seismological observations in the Pacific area, this Congress urges that the staff and equipment of the Observatory at Samoa should be increased, so that it may efficiently continue the good work already begun.

(9.) That, in view of the scientific and economic results which would accrue from the systematic study of the thermal region of New Zealand, the Pan-Pacific Science Congress strongly commends the proposal for the establishment of a seismological and volcanic observatory in that region.

ASTRONOMICAL NOTES.

The Transit of Mercury, 1924, May 7.

By D. M. Y. SOMMERVILLE, M.A., D.Sc.

ON May 8 (May 7, G.M.T.) the planet Mercury will transit across the face of the Sun. Transits of Mercury are not so rare as those of Venus, though sufficiently interesting to command universal attention. At present there are about thirteen or fourteen per century, while not more than two transits of Venus, on the average, occur in a century. The last transit of Venus occurred in 1882, and the next will not be till 2004. The year 1769 was an interesting one: on June 3 the famous transit of Venus was observed by Captain Cook at Tahiti; the expedition, which was organized by the Royal Society, is commemorated in the names Society Islands and Point Venus. On November 9 of the same year occurred a transit of Mercury, which was observed by Cook in New Zealand, and is commemorated in the name "Mercury Bay." In the year 1631 also transits of both planets occurred: they were remarkable as having been predicted by Kepler. The transit of Mercury was successfully observed by Gassendi, and occurred five hours later than the predicted time. The transit of Venus was missed, as it occurred during the night for European observers. The first transit of Venus actually observed was that of 1639.

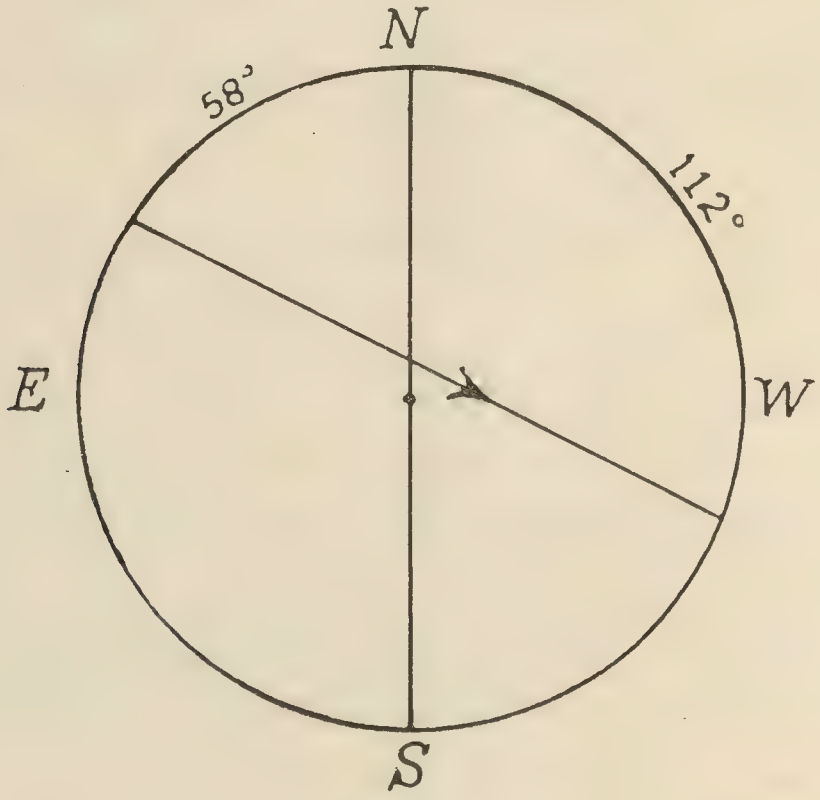

FIG. 1.

The transit of a planet across the Sun is a phenomenon of the same kind as a solar eclipse or an occultation; an eclipse of the Moon is quite different, being caused by the Moon entering the Earth's shadow. In the case of an occultation one still finds it convenient to speak of a "shadow." In a total solar eclipse the Moon, as it passes between the Earth and the Sun, casts its actual shadow on the Earth, and the total eclipse is visible only in the track of this shadow, a narrow belt a few miles wide. When the Moon is farther away at the time of the eclipse, and of smaller apparent diameter than the Sun, the apex of the shadow-cone falls short of the Earth and an annular eclipse is produced. We still, however, speak of the

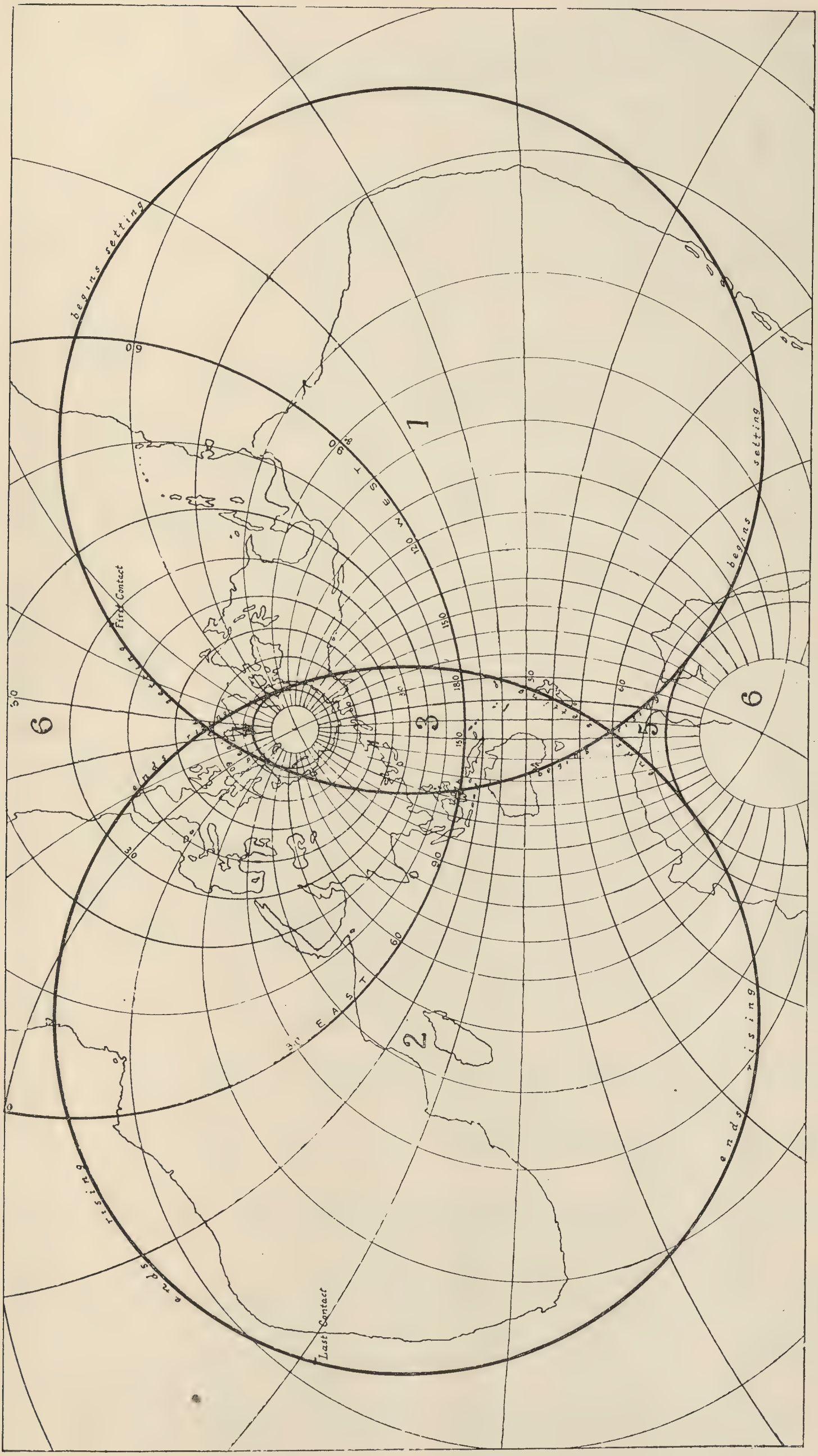
begins setting
begins setting
First Contact
Last Contact
ends rising
ends rising
WEST
EAST
1
2
3
4
5
6
6
0
30
60
90
120
150
180
150
120
90
60
30
0

FIG. 2.

"shadow," which in this case lies in the prolongation of the cone beyond the apex. But there is also the penumbra, or partial shadow, which in the case of the Moon is about 2,000 miles wide; from any point over which the penumbra passes a partial eclipse is visible. The Moon's shadow passes over the Earth in an easterly direction at a rate of about 30 miles per minute.

In the case of a transit of Mercury, owing to the small size of the planet and its nearness to the Sun, the phenomenon is of the nature of an annular eclipse. The shadow and the penumbra are nearly of equal size, and immense compared with the Moon's shadow or penumbra in a solar eclipse. Their diameters are respectively 133·8 and 135·5 times that of the Earth, so that their boundaries fall a long way outside the Moon's orbit. The centre of the shadow crosses the north and south line through the Earth at a distance of 13·5 Earth's radii to the north, and moves in a south-westerly direction at a speed of about 2,300 miles per minute. The westerly component is due to the fact that Mercury's motion is retrograde at the moment. In spite of its great speed the whole shadow takes nearly eight hours to cross the Earth. The passage of the edge of the penumbra across any spot marks the instant at which the transit begins or ends, the phases of first or last external contact; in the same way the passage of the shadow marks the instants of first and last internal contact.

Owing to the great speed and size of the shadow the time and appearance of the transit do not vary much in different parts of the globe. For this reason a transit of Mercury is almost valueless for finding the Sun's distance or parallax. The planet passes nearly centrally over the Sun, as shown in fig. 1.

As the edge of the shadow takes only about $3\frac{1}{2}$ minutes to pass right across the Earth, the whole of one hemisphere, approximately, will be in a position to see the beginning of the transit, and similarly, about eight hours later, another hemisphere will see the ending. These two hemispheres are represented by the two circles on the stereographic chart, fig. 2. Two parallels of latitude, 73° north and south, limit the regions of the Earth in which the planet never sets and never rises respectively. Six regions are thus defined on the globe, distinguished by numbers on the chart. They fall in pairs: 1 and 2, 3 and 6, 4 and 5 are of the same area and shape. They are characterized as follows:—

(1.) Only the beginning of the transit is visible; the planet sets before the end.

(2.) Only the end is visible; the phenomenon begins before the planet rises.

(3.) The whole transit is visible.

(4.) The beginning and ending are both visible, but the planet sets in between.

(5.) Part of the phenomenon is visible, but neither the beginning nor the end.

(6.) The phenomenon is entirely invisible.

The following times (N.Z. civil mean time) have been computed for Wellington:—

	d.	h.	m.	s.	
First external contact	May 8	9	15	31·5	a.m.
First internal contact	8	9	18	30·5	a.m.
Last internal contact	8	5	4	54·4	p.m.
Last external contact	8	5	7	53·9	p.m.

Sun sets at Wellington, 4 h. 51 m. p.m.

NATURAL-HISTORY NOTES.

Note on *Verconella dilatata*, by M. K. Mestayer.

An exceptionally large specimen of *Verconella dilatata* (Q. & G.) was picked up at Farewell Spit last December by Mr. Irvine, and presented to the Dominion Museum by Mr. H. Hamilton. The measurements are —length, 257 mm.; breadth, 98 mm. It is in very good condition, but unfortunately the animal was not in it, so the operculum was lost.

Chelifer in Ants' Nests, by W. W. Smith.

For many years I have observed numbers of these small pseudo-scorpions inhabiting the nests of ten of the twenty-two known species of New Zealand ants. They generally occur more frequently in nests located under large stones in open sunny situations than in nests located in or near the bush. When stones covering nests are raised and chelifers are present they generally remain motionless for a short time before concealing themselves in the larger galleries of the nest. I have also found them occasionally alone under small stones where there were no ants. Their persistent occurrence in ants' nests induced me to try some experiments with them in captivity. I secured six specimens, and placed them on fine damp soil in a small glass jar, and kept them in a dark but airy place under shrubs outside. I supplied them with living specimens of ants of several species, carefully counting the number before putting them into the jar. I also added a little suitable food for the ants, and daily observed the relations and actions of the two dissimilar forms to each other. In thus testing them I suspected that the chelifers were probably destructive in ants' nests. I first tried them with workers of *Huberia striata* Smith and *Monomorium suteri* Forel. I left them—four of each species—with the chelifers for six days. The latter did not molest the ants in the jar. I placed some eggs, larvae, and pupae of ants in the jar on the seventh day, and again left them together for six days. The chelifers consumed two pupa and three eggs of the small *M. suteri*, but did not molest those of the larger *H. striata*. I also tried them with species of aphis and scale insects, both of which are numerous on the roots of a number of plants occurring in the large cleared courts of the ants. The chelifers likewise consumed the eggs and young forms of these insects. The chelifers, being thus imprisoned, may be impelled by stress of hunger to attack and consume the eggs and minute insects as stated. Further experiments and observations will be continued to determine definitely the cause of their presence in ants' nests.

I recently covered part of the bottom of the glass jar containing the chelifers with damp blotting-paper, and placed thereon a number of various-sized winged and wingless forms of the rose-aphis (*Siphonophora rosae* Reaum.) and eggs of several blow-flies. They attacked and consumed many of the eggs and the wingless aphis. I supplied the latter with small fresh expanding rose-buds on which the aphis lived, but up to the present time the chelifers have not attempted to climb the tiny rose-shoots in quest of the aphis.

Judging from White's description of *Chelifer pallipes* (*P.Z.S.*, 1849, p. 6), I am impressed that it is a very variable species. There are, moreover,

in addition to *C. pallipes*, several undescribed species. I obtained a finely striped form in a nest of *H. striata* near Queenstown, but have not met with it in the North Island. Both sexes are more numerous in nests of ants occurring under stones on the open river-flats in Canterbury than in those that I have searched in the North Island. A reddish form occurs in the nests of the stinging *Tonera castanea* Mayr., located under prostrate logs in the kauri forests at Dargaville and Hokianga.

An Abnormally Coloured Specimen of the Yellowbelly (*Rhombosolea millari* Waite), by Gilbert Archey, M.A.

This fish is not abnormal in structure, as not infrequently happens in the case of unusually coloured or bicolorate specimens. It has been torn in the region of the ventral fin, where doubling, associated with delayed asymmetry, might perhaps be found, and any departure from the normal which may have been present cannot be noted.

The general coloration above (right side) is a marbling of pale yellow and white (colourless), with only moderately numerous, small, irregular blotches of brown, these coalescing to form fairly large, irregular brown areas near the dorsal and anal fins. There are also small reddish-orange spots interspersed among the brown. The lower surface (left side) is similar in ground colouring, but the brown spots are more regularly distributed, are darker in colour, and do not form irregular areas. Reddish spots are also present, but very sparsely. The anterior portion of the head is orange, as also are the fin-rays; the fin-membranes here and there carry dark pigment. The eyes and orbits are pigmented black, and lines of black dots occur along the caudal rays.

Microscopic examination shows, as was to be expected, that the abnormality consists simply in the absence, over the greater part of the upper surface, of the black, or melanim, component of the ordinary greenish-grey hue of this fish. This component is ordinarily undeveloped on the underside of flounders, but can be produced by exposure to light.

Cunningham and McMunn,* who by experiment caused the pigment to develop on the lower surface of flounders, demonstrated that the colours of fishes are due to the combined effect of three elements. The shining or iridescence is due to the interference and reflecting properties of small plates of guanin (iridocytes) formed from nitrogenous waste, while the actual colouring-matter is present in distinct branched cells, or chromatophores, of two kinds, one containing a yellowish pigment (of the lipochrome group), whose greater density usually forms the reddish spots, and the other containing black (melanim group), the greenish tinge being the result of the blending of both colours. A similar result is obtained by a combination of red and black or blue in the crustacea, in which case, however, the red alone occurs in chromatophores, the blue being held only in solution. Hence boiling or immersion in alcohol rapidly dissolves the blue, leaving only the red. Occasionally bright-red living crayfish are found, their colour being due to the absence of the blue component. Fishes, having both components in chromatophores, do not lose their colours so readily on boiling, but exposure to light and long immersion in alcohol, either separately or together, will bleach them.

The fish which forms the subject of this note was presented to the Canterbury Museum by Mr. W. O'Connell, to whom the Museum has been indebted on several occasions for interesting specimens of our marine fauna.

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* CUNNINGHAM and MCMUNN, *Phil. Trans.*, 184, p. 765, 1893.

REVIEWS AND ABSTRACTS.

The New Physics: Lectures for Laymen and others, by Arthur Haas. Authorized translation by Robert W. Lawson. Methuen and Co., Limited, London. 6s.

The rapid advances made in physics during the recent years have made it impossible for the student and the layman to keep pace with modern developments, and most of the books that have been written on the results of contemporary research have been intended more particularly for the specialist. Professor Haas is an eminent authority and exponent of modern physics, and in *The New Physics* he has supplied a long-felt want by presenting a connected and illuminating account of the present-day structure of physics, in such a form that it should prove of value to, and within the reach of, the average scientific reader.

The reviewer cannot agree that the book is one for laymen unacquainted with the elements of physics and chemistry, but nevertheless it can be confidently recommended to teachers, amateur astronomers, and scientists generally. The book is written by a scientist who knows intimately the subjects he writes about, and not, as is frequently the case in popular treatises, by one who has acquired a superficial knowledge for the purposes of writing a book to bring in royalties.

The contents are—I, The Electro-magnetic Theory of Light; II, Molecular Statistics; III, The Electron Theory; IV, The Quantum Theory; V, Theory of the Chemical Elements; VI, Theory of Relativity and of Gravitation.

The style is somewhat stilted at the beginning of the book, but later, particularly in IV, V, and VI, as the translator gets on to happier ground, the subject is dealt with very lucidly.

Modern physics and chemistry owe much to the spectroscope introduced by Kirchhoff and Bunsen in 1859, not only for its practical uses, but because it has led the way to most of the great theoretical advances of the last half-century. When Maxwell's electro-magnetic theory of light was propounded in 1873 it appeared as though we were within sight of a complete knowledge of the main principles of the physical universe, and that in future developments mathematics would be the general tool. There remained, however, two main outstanding problems—namely, the explanation of the complicated spectra of simple gases, and the experimental facts of electrolysis as laid down by Faraday in 1833. It was experimental work on the former elucidated by the latter which has led successively to the discovery of cathode rays, the atomic nature of electricity, conception of electro-magnetic mass, X-rays, radio-activity, theory of relativity, Rutherford's theory of atomic structure, and Bohr's work on the origin of spectral lines.

The story is a fascinating one, and is well told by Professor Haas. It is unfortunate, however, that the author gives credit to many "continentals" for the various landmarks of discovery when the claims to such credit are very doubtful. This fault is recompensed, however, by the

value of the additional insight given to the reader from the German (Austrian) point of view in the book, this attitude being in some respects more philosophical than the more experimental outlook of the English-speaking races.

The volume presents us with a picture of nature of great simplicity. In reality it is not nature that is complicated, but only the path which leads us to a true knowledge of nature. This path was complicated from the narrow limitations of the human senses, and because theoretically physics only gradually succeeded in liberating it from human points of view. This is Einstein's great achievement. Indeed, the greatest benefit which arises from the recent discoveries elucidated in the book under review is the reduction of the various sciences of physics and chemistry to one basic foundation, which will, within the next few years, make the beginner's approach to the study of science much more easy and direct and with a minimum of premise. We may well envy the future beginner in the study of science in that he will have his chemical atoms, his electricity, heat, light, &c., introduced as concrete realities simply pictured and connected instead of having to build on warped imagination and disconnected facts.

E. M.

Vector Analysis, by C. Runge, Professor of Mathematics in the University of Göttingen; translated by H. Levy, M.A., D.Sc., F.R.S.E., Assistant Professor of Mathematics at the Imperial College of Science and Technology, London. Methuen, London, 1923, pp. viii to 226.

The immense interest which has been provoked by the theory of relativity has been reflected in vector analysis, and especially in the calculus of tensors, which is admittedly the most natural—in fact, the almost inevitable—vehicle for exploring the world under relativity conditions. It is scarcely too much to say that Einstein's theory could not have advanced beyond the restricted stage without its aid; it was indeed fortunate for Einstein that the calculus of Ricci and Levi-Civita was ready to hand.

The present volume, the German original of which appeared in 1919, deals only with vector analysis of euclidean space of three dimensions. As is perhaps natural in the case of a German writer, much inspiration has been derived from Grassmann's extensive calculus, and the author has done a distinct service in enriching vector analysis by a blending of Grassmann's ideas. The first chapter develops the elementary theory of vectors, and the notation in respect of vectors and their products is that of Gibbs, using the dot and cross. The proofs are given with care, but, curiously, the fundamental laws, commutative and distributive laws, are only mentioned casually twenty or thirty pages after having been stated; the associative law is glossed over and not even mentioned. Grassmann's "external product" (usually translated, however, "outer") is made much use of, with the notion of "complement." "Representation" is not a very happy equivalent for Grassmann's "Ergänzung"; but the idea of complement scarcely acquires its full meaning in a space of only three dimensions. It is strange, too, that in the application to determinants the determinant notation is never used. In the second chapter the author

treats of differentiation and integration, and introduces the fundamental ideas of "gradient," "divergence," and "rotation" or "curl." Applications are given to curvature and torsion, central orbits, motion of a fluid, Green's theorem, &c. The third and last chapter is devoted to tensors, starting from the point of view of the affine transformation of space which leaves the plane at infinity unaltered. But the restriction to euclidean three-dimensional space again prevents the idea of tensors from acquiring its full meaning. Runge's tensors are virtually Gibbs's dyadics, and are most readily understood from the theory of strains. The general idea of tensors, with the distinction of covariant and contravariant vectors, is not hinted at. One will await with interest the development of the general theory which is promised in the second volume.

On the whole the translation is satisfactory, but the number of misprints is decidedly excessive, and the diagrams are scarcely worthy of the book. A curious slip, doubtless on false analogy with the word "gradient," is "cogradient" instead of "cogredient."

D. M. Y. S.

Practical Mathematical Analysis, by H. von Sanden, Professor of Mathematics at the University of Clausthal; with Examples by the Translator, H. Levy, M.A., D.Sc., F.R.S.E., Assistant Professor of Mathematics at the Imperial College of Science and Technology, London. Methune, London, 1923, pp. xv, 195. 10s. 6d. net.

Although well-developed methods of practical computation have been in use by astronomers, engineers, physicists, and even pure mathematicians ever since tables have had to be computed, it is only within recent years that, in England at least, any systematic courses of mathematical laboratory instruction have been provided, and the present volume is one of the first in the English language to deal explicitly and comprehensively with this part of a mathematician's equipment. "The contents of the book cover a portion of the work included in the courses on numerical and graphical calculation held at the University of Göttingen under C. Runge." While it does not aim at completeness, its comprehensiveness may be judged from the following list of topics: The slide-rule and calculating-machines, Horner's solution of equations, extrapolation and interpolation, numerical and graphical integration and differentiation, smoothing of empirical curves, harmonic analysis, method of least squares, iterative and other methods of solving equations, graphical and numerical solution of differential equations. Graphic statics has been reserved for another volume, and very little is said about nomography, reference being made to d'Ocagne's treatises. The translator has wisely added many practice examples, a deficiency in which is rather a common fault of Continental treatises.

The book concludes with a list of works of reference, mostly German. It is a pity that the translator did not add the corresponding English reference books, where these are available.

D. M. Y. S.

CORRESPONDENCE.

Foreign Shrimps in New Zealand.

SIR,—In the December number of your *Journal* appears an interesting article by the Hon. G. M. Thomson bringing up to date his most valuable book, a work for which all interested in acclimatization matters must be ever grateful.

There is one section of the article, however, which I think might well have been omitted, as it deals not with an introduced but an indigenous species; moreover, the tone of the article might lead some who do not know Mr. Thomson to think it was merely inserted as an excuse for one more castigation of acclimatization societies. I refer to the paragraph headed "Foreign Shrimps."

It is a pity that Mr. Thomson did not at least make sure of his facts before getting to work with his scourge. We are indeed lucky in having such an eminent authority as Dr. Chilton in Christchurch, and I myself have, on behalf of the acclimatization society, frequently consulted him in reference to shrimps and other matters, and it is hardly necessary to add that he has generously given us the benefit of his knowledge. In particular, before carrying out the experiment in question I consulted him as to the feasibility of breeding *Xiphocaris curvivortris* in the gardens, and he told me he thought it might be possible, as the species bred in fresh water and was at one time plentiful in the Avon. It was in consequence of this information that the experiment was tried, to ascertain whether the shrimps would breed in captivity, which, Mr. Thomson must realize, is a somewhat different thing from breeding in fresh water.

I and some other members of the Council have felt for some years that the liberation of large quantities of trout in our streams is now unnecessary, and that if we could breed and liberate several million shrimps annually under conditions such as suggested by Mr. Thomson in his book (p. 230) we should be doing a more valuable work.

I should be glad if Mr. Thomson could inform me on what authority he states that this species has "been eaten out in streams stocked with trout" ("Naturalization, &c.," p. 508). I can show him several streams near Christchurch very heavily stocked with trout in which this particular shrimp is present in countless millions and forms the principal food-supply of the trout. Does Mr. Thomson know for certain that this shrimp was ever plentiful in the Selwyn or Opihi, for instance? If so, why is it now rare or extinct in these rivers whilst swarming in the Cam, the Ashley, and certain other streams north of Christchurch? If Mr. Thomson can answer these questions he will help our society in its work.

I do not wish to comment on the justice of Mr. Thomson's gibe that our society thought it was making "new discoveries." I can safely leave this to the judgment of your readers. At best the gibe is admittedly based on a mere newspaper report, and as a politician of many years' standing Mr. Thomson will realize that these are not invariably accurate.

M. H. GODBY.

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VOL. VII. WELLINGTON, MAY, 1924. No. 1.

THE WORK OF THE JOURNAL.

THIS is the first number of a new volume of the *New Zealand Journal of Science and Technology*. The editors of the *Journal* have endeavoured to make it fill an obvious vacancy in the periodical literature of the Dominion—that of a magazine available to all classes of readers and open to receive the contributions of scientific workers in all fields. It is now felt that the *Journal* may well be made more acceptacle to the general reader without sacrifice of its scientific value; but this object can be attained only with the co-operation of those who are willing and able to write for it. That there are in New Zealand any number of people capable of making useful contributions to the community's fund of knowledge goes without saying; and a country in active development in all directions bristles with subjects that can be usefully and interestingly dealt with. The editors invite contributions on all subjects of a scientific or technical character, up to, say, eight thousand words in length, and will be glad to publish such as are of interest to thinking readers.

Keeping in view the object of making the *Journal* a magazine for the public as well as the scientist, articles whose object is to place on record mere descriptions or observations couched in highly technical language will have to give place to those which are intelligible to non-experts, particularly as such contributions can readily be published in more appropriate form. The *Journal* affords primarily a place in which the scientific worker can bring the results of his work before people not readily reached by other means. The expert will here not be writing solely for colleagues similarly expert. Ideally there should be no article in the *Journal* which will be rejected as unreadable, or even as without interest, by those whose tastes lead them to such a publication.

The category of acceptable contributions is by no means confined to matter of New Zealand origin. Accredited matter from outside sources, of interest to readers in this country, will be welcomed; and abstracts from or reviews of publications dealing with subjects within the scope of the *Journal* will, as hitherto, be published.

ELECTRIC-POWER SERVICE LINES FOR COUNTRY DISTRICTS.

By LAWRENCE BIRKS, B.Sc., M.Inst.C.E., M.I.E.E., &c., Chief Electrical Engineer, Public Works Department, Wellington, New Zealand.

THE possibilities of electric-power supply to isolated farming districts and country consumers is probably being exploited, in proportion to its population, more extensively in New Zealand than in any other country in the world, as a result of the Government system of bulk supply of hydro-electric power and of the Electric-power Board organization for its distribution.

The whole conception of the Government hydro-electric scheme is based on the ideal that, as soon as it is commercially remunerative, every farm should have access to a supply, subject to a guarantee of revenue from such service. It is calculated that in order to ensure financial success the supply authority must have a guaranteed return of at least $12\frac{1}{2}$ per cent. on the capital outlay on any extension for a period of ten years, or 20 per cent. for a period of five years, before being compelled to erect such extension. The latter minimum has been adopted in the regulations issued by the Government of New Zealand for the control of electric-power supply—clause 7 (*d*)—by which all reticulating authorities in the Dominion are governed. This clause reads as follows :—

> (*d.*) If an extension to the licensee's main is required to give supply to any consumer or group of consumers, the licensee shall erect such extension within a period not exceeding twelve months, on condition that such consumer or consumers, jointly or separately, shall give to the licensee a guarantee to pay for electricity supplied over such line a total amount in each year for a period of five years of 20 per cent. of the estimated cost of such extension, and thereafter all electrical energy shall be chargeable at the ruling rates for the district. Notwithstanding any such payment, the line shall remain the property of the licensee, and may be used for such other purposes as may be required by the licensee provided the supply to the contributor or contributors is not thereby prejudicially affected.

This gives ample protection both to the ratepayer or prospective consumer in enabling him to demand a supply under reasonable terms, and to the supply authority in enabling it to demand a remunerative guarantee before giving such supply.

Both parties being thus protected, it may be assumed that as soon as a scheme is formulated for a district and installed under these regulations every resident within that district, however remote, has access to a supply of electric power, on giving a suitable guarantee. The critical question then becomes, What distance from the main line will it pay to run branch service-lines for one or more houses or farms under such guarantee ? In general, if a revenue of £50 per mile of line is available this will justify the supply authority in erecting the line at a cost of £250 to £350 per mile without asking any guarantee. This enables a full three-phase line to be run. But when the return is less than £50 per mile the extension should only be run subject to a guaranteed revenue being obtained.

The question then becomes one of the cheapest cost at which such extension or branch can be erected. The cheapest lines that can be constructed consist of galvanized-iron wire, and the smallest size that it is advisable to employ is No. 8 S.W.G., weighing 400 lb. per mile of wire—

i.e., 1,200 lb. per mile of three-phase line. Such a line will have the capacity and characteristics as set out in the table below, allowing 6 per cent. drop in the line exclusive of transformer losses. The quality of wire on the market as ordinary fencing-wire is very variable in electrical properties. A special quality of pure iron is usually specified for telegraph purposes, having a direct current resistance of 13·3 ohms per mile. But for the cheapest possible lines ordinary fencing-wire is quite as serviceable, with a resistance of about 15 ohms per mile, and this has been taken as the basis in the following calculations. Moreover, with iron wire the resistance and reactance increase with the current, owing to "skin effect," up to a maximum of 23 ohms per mile, and this effect has been taken into account.

The standard pressure employed in New Zealand for three-phase distribution-lines are 400, 3,300, 6,600, and 11,000 volts, and the tables are worked out for these pressures.

	Voltage.			
	400.	3,300.	6,600.	11,000.
Maximum distance of transmission with a load of—	Miles.	Miles.	Miles.	Miles.
1 h.p. (1 K.V.A.)	0·72	54	*	*
2 h.p. (2 K.V.A.)	0·32	27	*	*
5 h.p. (5 K.V.A.)	0·10	10	42	*
10 h.p. (10 K.V.A.)	..	5	20	58
20 h.p. (20 K.V.A.)	..	2	9	28
Maximum load (h.p.) at a distance of—	H.p.	H.p.	H.p.	H.p.
One mile	0·75	35·0	116	265
Five miles	0·14	9·6	35	89
Ten miles	0·07	5·2	19	50
Pole-spacing (chains)	3 ch.	3 ch.	3 ch.	3 ch.
Poles per mile	26·6	26·6	26·6	26·6
Length of poles (feet)	30 ft.	30 ft.	32 ft.	35 ft.
Price of poles, c.i.f.	44s.	44s.	48s.	54s.
Insulators per mile	80	80	80	80
Price of insulators, c.i.f.	1s.	1s. 6d.	2s.	4s. 6d.

* Over 100 miles.

The above prices provide for substantial Australian ironbark poles (*Eucalyptus paniculata*, *E. crebra*, or *E. siderophloia*) at least 10 in. in diameter at the butt. These poles will have a normal life of twenty-five to fifty years, and thus largely exceed the life of any European or American timber. The cost can be reduced by using poles of smaller diameter, from 6 in. to 8 in., which are strong enough; but with Australian ironbark the timber is not sufficiently mature at this size to give the full life to the pole that is available with a pole having a butt diameter of 10 in. A small saving can be effected by using mixed Australian hardwoods—tallow-wood (*Eucalyptus microcorys*), grey-gum (*Eucalyptus propinqua* or *Eucalyptus punctata*), red mahogany (*Eucalyptus resinifera*), black-butt (*Eucalyptus pilularis*, &c.)—instead of ironbark, but again at the cost

of a shorter life. The cost of renewal of these lines is such as to fully justify the use of the higher class of timber.

On this basis the cost per mile of the three-phase construction, exclusive of wayleaves, tree-cutting, and special work—that is to say, the cost of construction along the roadside in ordinary open country within an average of ten miles of a railway-station for delivery of material—is as follows :—

	Voltage.			
	400.	3,300.	6,600.	11,000.
	£	£	£	£
Poles—supply	58	58	64	72
Poles—delivery	25	25	27	30
Poles—erection	20	20	22	25
Cross-arms and ironwork	3	3	3	4
Insulators	4	6	8	18
Wire (1,200 lb.)	12	12	12	12
Erection of wire	12	12	12	12
	134	136	148	173
Survey and engineering expenses ..	16	20	22	25
Totals	150	156	170	198

Tree-cutting and wayleaves on roads in open country do not add to the cost, but under average New Zealand conditions will add £10 to £15 per mile to this cost.

In addition, the transformer substation, transformer (5 kw. per service) meter, and service for each transforming-point will cost as follows : 400 volts (no transformer), £5 ; 3,300 volts, £25 ; 6,600 volts, £40 ; 11,000 volts, £60.

The annual guarantee required for a service up to 5 kw. at a distance of two miles from a 3,300-volt line would thus be 20 per cent. of £337—*i.e.*, £67 per year for five years, or £42 per year for ten years. This is a reasonable cost if shared between two or three consumers. But for single consumers and for larger distances a cheaper type of construction is necessary. Moreover, for this type of service the three-phase system is proving unduly complicated, and the advantage of the simplicity of the single-phase system results in an actual saving in cost. If a large-capacity cooking-range is installed, connected to one phase and taking up to 5 kw., it involves on the three-phase the installation of a 15 kw. transformer, whereas the diversity of this load with the lighting and other uses would enable the whole service to be supplied from a 5 kw. single-phase transformer well within its overload capacity. The single-phase system also slightly reduces the cost of switches, fuses, insulators, meters, and all accessories, particularly where one phase is permanently earthed and therefore not switched, thus reducing the switch from a triple pole to a single pole.

The experience of the Southland Electric-power Board is that with standard three-phase lines averaging in cost £375 per mile, including transformers, the revenue necessary to make a line pay is £75 per mile

of line. This is fairly heavy, and a cheaper type of construction is apparently required to render the supply generally available to the back-country farmer, who is probably a mile away from his nearest neighbour.

The Dunedin City Council has been supplying in the farming district of Taieri County for some years, and the result of their experience is well expressed by the City Electrical Engineer, Mr. M. C. Henderson, as follows :—

> Single-phase transmission for country consumers was originally adopted to keep down the cost of construction, and so help out the country consumer who required only lighting and small-capacity heating and not power. We have always required, either in town or country, a minimum guarantee for a period of years where there appears to be no prospect of a fair return on the cost of extension, and in the country especially it was necessary to keep this as low as possible. Hence the adoption of single phase for primary distribution, with star connection, the neutral point of transformer being earthed. With the tightening-up of regulations, and the consequent increase in the cost of earth connections, delta connection is being substituted in some cases, with two wires. In the past practically all power-supply has been given on three-phase system, with three single-phase transformers connected in star with the neutral earthed. The almost certain increase in demands by present and prospective consumers in the near future, both for power and heating, has raised the question as to the most economical system of supply both for the consumer and the supply authority. The use of milking-machines and cream-separators is extending very rapidly, calling for power-supply. It is confidently anticipated that a large number of the same consumers will adopt electric cooking before long, which will mean a demand of 5 kw. to 6 kw. With two or three consumers to the mile, separate transformers will be required for each if the houses are more than a few chains apart. If three-phase supply is given, the cooking-load will have to be balanced on the three phases, or one transformer of larger capacity than the other two installed to deal with the cooking-load. This aspect of the problem has carried us a step further, to consider single-phase supply for farming consumers; and there is much to commend it. Lighting presents no difficulty, cooking is simplified, as the maximum voltage will be 230; the chief obstacle is the power, and this difficulty is largely eliminated by the modern single-phase motor, with satisfactory starting and power-factor characteristics, and reliability. The only drawback is the increased price of the single-phase over a three-phase power motor of equal capacity. So far as the consumer is concerned, this is the only objection that can be raised. From the supply authority's point of view the advantage of single phase is that one transformer of 5 kw. capacity will deal with the whole load, consisting of light, heat, and power. If light and power only are required, 2 kw. will probably meet the case, and it can be changed for one of higher capacity at a minimum cost when cooking is added. The cost of one single-phase transformer of 5 kw. capacity compared with one three-phase of equivalent capacity, or three single-phase, is such that the saving to the supply authority is more than the increased cost of a single-phase motor, apart from other advantages. By agreeing to pay the increased cost of the single-phase motor (about £15 for the usual 2 h.p. size), the supply authority can remove any reasonable cause for objection by consumers, and a considerable credit balance will still be shown on the cost of installing transformers, in addition to the other advantages mentioned. The Dunedin City Council has decided to adopt this system, retaining the right to decide each case upon its merits, and supply either single-phase or three-phase as may be found most economical. Consumers will be balanced against one another on the three-phase, and, as they will all be of the same class, with their demands occurring at the same time, this should be perfectly satisfactory.

The recent improvements in single-phase motors, particularly in respect to power-factor and starting characteristics, has emphasized the advantage of the single-phase system for this purpose.

The three-phase system has a great disadvantage in that a single fuse may blow and leave the motors operating single-phase, with great liability to burn out unless protected with special circuit-breakers, which again add to the cost. This difficulty is entirely overcome on the single-phase system, and with a mixed cooking and farm-motor load in which one phase

is liable to be overloaded independently of the others this may be a determining consideration. In order to enable the single-phase system to be adopted generally for this service with the cheapest type of construction, a special regulation—clause 24 (*f*)—was introduced into New Zealand in 1922, permitting a single-wire system with earth return for circuits not exceeding 20 kw. capacity.

In order to meet the objection of possible interference with telephone circuits, this system is limited to districts more than six miles from a central telephone exchange. Within this radius the conditions are usually suburban and the single-phase system would not be required. Using only the star voltage the pressure is not so high, and the distances are therefore more limited, though still ample for practical purposes. The corresponding tables of capacity for a single-phase circuit consisting of a single No. 8 S.W.G. galvanized-iron wire at various voltages, allowing 6 per cent. line-drop, are as follows :—

	Star Voltage.			
	230.	1,900.	3,810.	6,350.
Maximum distance of transmission with a load of—	Miles.	Miles.	Miles.	Miles.
1 h.p. (1 K.V.A.)	0·24	18·0	*	*
2 h.p. (2 K.V.A.)	0·11	9·0	36·0	*
5 h.p. (5 K.V.A.)	..	3·4	14.0	39
10 h.p. (10 K.V.A.)	..	1·6	6·8	19
20 h.p. (20 K.V.A.)	..	0·7	3·2	9
Maximum load (h.p.) at a distance of—	H.p.	H.p.	H.p.	H.p.
One mile	0·25	12·0	39·0	88
Five miles	0·05	3·2	12·0	30
Ten miles	0·02	1·7	6·4	17

* Over 50 miles.

The costs of such a line per mile are as follows :—

	Star Voltage.			
	230.	1,900.	3,810.	6,350.
	£	£	£	£
Poles—supply	58	58	64	72
Poles—delivery	25	25	27	30
Poles—erection	15	15	17	20
Insulators	2	3	4	8
Wire (400 lb.)	4	4	4	4
Erection of wire	6	6	6	6
	110	111	122	140
Survey and engineering expenses ..	15	16	18	20
Totals	125	127	140	160

Of course, with the earth return great care must be given to the earth connection, as a fault or high resistance in this may liven at a fatal pressure portions of the wiring usually at earth potential, and thus introduce a risk of fatal accident. The difference in cost between the single-wire and two-wire lines is so small that this will be the determining factor in many cases in favour of the single-phase circuit with two wires at delta instead of star voltage.

The Dunedin City Council have seventeen such single-phase earth-return service connections in operation at 1,700 volts star pressure, with loads ranging from 1 kw. to 27 kw., and at distances of one-half up to two miles and a quarter from the connection to the mains, and the system has proved very serviceable.

The whole question of electric-power supply to the back-country farmer is of such vital importance in helping to prevent the drift of population to the cities that no apology need be offered for analysing this problem in considerable detail, particularly as it is not generally realized what distances can be covered with No. 8 galvanized-iron wire for small demands.

I have to acknowledge the assistance of Mr. A. C. Caldwell, B.E., in the preparation of the tables herewith, and of Mr. M. C. Henderson (City Electrical Engineer, Dunedin), Mr. J. R. Templin (Consulting Engineer, of Christchurch); and Mr. H. R. Thomas (Engineer to the Southland Electric-power Board) for details of the results of their experience in the construction of cheap country service-lines.

THE ORIGIN OF PLANETS.

By A. C. GIFFORD.

EVER since Copernicus proved that the Sun, and not the Earth, is the centre of the solar system, man has been impelled to inquire how the marvellous arrangements of matter and motion that exist within that system came about. No one can entertain for a moment the idea that they are the work of chance. It is felt that the configurations and motions of this matter in the far-distant past must have led to the present configurations and motions by an orderly course of evolution, in which all known and unknown natural laws have been obeyed. It is recognized that if human knowledge and intelligence were equal to the task it would be possible to infer, from the circumstances of the present, those of any epoch in the ages that have gone or in those that are still to come. So far, however, we can see but a very little way along the backward or the forward path.

For two hundred years after Copernicus the problem of the origin of the solar system remained the dominant one in the whole range of cosmogony. But as the development of optical instruments and the indefatigable labours of astronomers pushed back the boundaries of the known universe, first the Earth and then the giant Sun sank into comparative insignificance, and it was realized that the whole solar system is but an atom in the immensities of space. Except for our personal interest in our immediate surroundings the problem of the known planets is no more important than that of the planets of any other star in the galaxy,

or even of a star in some much more distant cosmical system. The modern outlook changes the whole nature of the problem. It is now easier to study the life-history of the galaxy than that of our own Sun and its attendant planets. The present conception of the universe exceeds in sublimity a millionfold that which was possible when stars were merely points of light, and when such particulars as temperature, chemical composition, and radial motion were not only unknown but believed to be unknowable.

Taken by themselves, the problems presented by the Sun and planets appeared then well-nigh insoluble. Taken as a corollary to some of the conclusions with regard to the life-history of a typical star, many of the difficulties disappear.

The remarkable speculations of Wright and Kant led to the dawn of modern cosmogony, but they were eclipsed by the nebular hypothesis suggested independently by Laplace in 1796. This has dominated astro nomical thought ever since. There is a fascination about the picture he gave us of the great masses of glowing and rotating gas, shrinking as the result of radiation of energy, whirling ever faster and faster as they shrink, and throwing off from time to time rings of matter in their equatorial planes. The idea is so attractive that astronomers have applied it to systems of every size, and now, although some insuperable objections have been urged against its application to the solar system, no cosmogonist can free himself completely from its sway, and every cosmical body and every system, whatever its shape or form, is spoken of as starting its life-history in a state of wide diffusion as a whirling cloud of gas.

However beautifully worked out it may be, such a theory cannot prove altogether satisfying, as the evolution traced is all in one direction, and appears to lead inevitably to the extinction of all luminous life. Can we accept such a theory without asking for an explanation of the origin of these whirling masses of gas? An enduring process must be cyclic. Unless there is some way of starting the process again, some adequate means of rejuvenation, the end must be universal death.

The ablest and most attractive modification of Laplace's theory, adapting it to the fuller knowledge of the present day, is that of J. H. Jeans, published in the Halley Lecture of 1922. Jeans comes to the surprising conclusion that the hypothesis, when slightly modified, is capable of explaining nearly every cosmical form except that of the solar system for which it was specially designed. If there are solar systems like ours throughout the galaxy, developing out of whirling masses of gas, we cannot hope to see them. Even at the distance of Proxima Centauri a planet like Jupiter would be quite invisible to us, even with the greatest telescope. For systems of this order observation is powerless—we are dependent on theory; and theory declares that the mass of such a system is insufficient to allow it to follow the Laplacian order of development. It is quite different, however, with gigantic systems like the spiral nebulae or the galaxy. Jeans believes that all the vast elliptical, lenticular, and spiral nebulae can be arranged in a regular sequence and shown to lie on one continuous evolutionary chain. He pictures all as starting in the form of rotating gas; but the condensations which form out of the ejected matter are incipient suns, not planets. The lecture is full of interest, and many parts of it call for discussion, but space forbids.

In a discourse delivered at the Royal Institution on the 15th February, and published in *Nature* on the 1st March, 1924, Jeans returns to the problem, and discusses especially the origin of the solar system. He finds

that it cannot have developed from an undisturbed mass of rotating gas. He is very unwilling to allow the possibility of an encounter with another star, or even a very close approach between two stars; but in this case there must have been some such disturbance. On account of the *a priori* improbability of stellar encounters, Jeans concludes that our solar system cannot lie on the main line of evolutionary progress; that it is certainly exceptional and possibly unique. The necessary disturbance which made the birth of planets possible he believes to have been of the nature of violent cataclysmic tidal action during an exceptionally near approach of another star to our Sun.

Before proceeding to a detailed discussion of the tidal action of one star on another, Jeans says: "It is true that a head-on collision between two astronomical bodies would produce more immediately dramatic results than a mere tidal pull; *but we shall not consider such an event here.* Head-on collisions must of necessity be exceedingly rare; systems that experience them would undoubtedly be deflected from the main line of evolutionary progress on to a branch line; *but it does not seem likely that this branch line contains systems like our own.* As time does not permit the exploration of all conceivable branch lines, let us turn at once to that which seems most likely to reveal the origin of our system—the branch line that diverges from the main line at the occurrence of a violent tidal encounter."

It is unfortunate for the advance of cosmogony that Jeans decided not to consider at present more complete encounters than those of a tidal character. When he does so the results will be startling. That he has refrained from considering them is clear from the very first sentence here quoted. It was pointed out by Bickerton in 1878 that a direct head-on collision, as observed from distant space, is one of the least dramatic forms of encounter. It is even doubtful whether it would be as spectacular as the particular form of encounter finally selected by Jeans as the probable cause of origin of the peculiarities of the solar system.

On the Essential Difference between the Phenomena resulting from a Grazing Impact of Two Stars and those which follow a Complete Collision.

It is often assumed that the phenomena which follow a grazing impact of stars are alike in kind to, and differ only in degree from, those which follow a more complete collision. This is by no means the case. The former, though exceedingly transient, is the most spectacular event in nature; the latter is very much less noticeable, though far more enduring. The former causes a sudden rise in brightness of ten or twenty magnitudes, the latter barely of one. The graze strews space with cosmic dust; the direct impact scatters comparatively little material. The two cases were contrasted in a paper by Professor Bickerton published in vol. 11 of the *Transactions of the New Zealand Institute* (1878). The want of recognition of this contrast is so general that it may be well to go a little more into detail.

The temperature of a body struck from two stars in a partial impact depends on the velocity destroyed. The resulting mass is therefore as hot as the body formed by a complete collision of the two stars would be. At the moment collision starts, disregarding tidal distortion for the moment, the centres of the stars are at a distance apart equal to the sum of their radii. The velocity is the same, therefore, at this moment, whether they

are just about to graze or to come into direct collision. But though the initial temperature produced by the clash is the same in the two cases, its effects are widely different. Neglecting original proper motions, which are always small compared with those produced by gravitation, the two stars meet with parabolic velocity. The parts which come directly in one another's way are stopped. Unless the collision is sufficiently direct, the wounded stars go on. Of the kinetic energy transformed in the impact, a portion remains as energy of rotation, except when the impact is perfectly direct; but in all cases the bulk of it is changed into molecular heat agitation. The effects of this heat energy depend on the mass. In the case of complete coalescence a great part of this energy is immediately used in producing expansion. If the stars are equal and entirely gaseous before impact the transformed energy is just sufficient to expand the resulting body till its diameter is twice that of either original star, and its temperature the same as that existing before the collision. The expansion against the gravitation of the combined masses involves such a vast expenditure of work that the temperature of many millions of degrees centigrade, which is produced by the impact, disappears during the early stages of the expansion. Except for a very brief flash of light of short wave-lengths, approximating to those of X rays, the resulting brightness is only four times that of a single star, or double that of the pair. That is, the star, viewed from our system, appears to have increased in brightness by less than one magnitude; and there are reasons why it should appear even less than this. In the sudden transformation of kinetic energy of translation into heat, all chemical elements are treated alike, and so directly after the encounter all elements have equal average molecular velocities: that is, they are at widely different temperatures proportional to their atomic weights. An approach will be made towards equipartition of energy, the light atoms gaining heat from the heavier. This will result in selective molecular escape, and the lighter molecules will be expelled to distances greatly exceeding the doubled radius. They will form a vast atmosphere, at a lower effective surface-temperature, which will diminish the apparent brightness still further. The event is the birth of a giant M star with a low surface-temperature. If the stars are dense bodies before the impact, although the initial temperature will be much higher, the surface will be so small during the brilliant stage that, viewed from afar, the resulting brightness will be even less than if they had been originally gaseous. Some of the energy of collision will be used up in raising the two bodies to the gaseous state. In this case the actual increase of brightness may be through many magnitudes, but, as the original stars were invisible to us, the birth of the giant may be quite unnoticeable. The effect, though essentially undramatic, is enduring. The giant star so born will, in the course of thousands of millions of years, pass through the usual sequence of changes and fade away as a dwarf.

Very different are the phenomena associated with a cosmic graze. The wounded suns pass on, each with a brilliant scar, and flash variable lights as they spin away through space. The portions which meet are stopped, and form the most violently explosive body known in the whole realm of nature. They coalesce temporarily into a single rotating mass, but it is marvellously constituted. The lighter materials, torn from the outer portions of the encountering stars, are within, wrapped round by heavier matter that has come from the deeper parts of the grooves. The whole mass of this third body is approximately at the same average temperature as a body formed by complete coalescence would have been. But the difference

of mass alters the case completely. This body is thermodynamically unstable, too hot to hold together. Gravitation is powerless to prevent its indefinite expansion. If the graze is slight, every particle may have a velocity of molecular agitation far greater than the critical velocity of excape. There is nothing so stop the outrush of matter, and expansion will continue until the entire body is dissipated in space. During this outrush there will be an interchange of energy amongst the different chemical elements. Every time a light molecule encounters a heavy one it receives some energy from it. Iron is initially fifty-six times as hot as hydrogen, but there will be a continuous approach towards uniformity of temperature characterized by equipartition of energy.

We have already noticed that the third body is constituted in a very anomalous manner, the light gases from the atmospheres of the two stars being wrapped round by heavier matter from below. During the first stages of the expansion the heavier materials will be urged outwards by the pressure of the lighter gases within. But when the body has grown to considerable size, which it will do very quickly, the light gases, having acquired very high velocities, will gradually find their way to the outside, and the heavier nucleus will be enclosed in a shell of hydrogen and helium, the outer portions of which will be expanding at a rate of 1,000 miles per second or more. In twenty-four hours the radius will equal that of the Earth's orbit, and there will hardly be any diminution of temperature, as the work done in escaping is so small a fraction of the energy available. The increase in brightness will be extremely rapid for a time, owing to the quick increase of radiating surface. The retreating suns will be overtaken by the outrushing gases from the third body, and will for the time be hidden within it. Their surfaces will be heated by the impact of the molecules of gas. But the expansion leads to rapid decrease of density, and as the gases fill wider and wider regions of space their molecular encounters become less frequent and the brilliant light fades away. This is not a case of cooling. The molecular velocity is only slightly changed. The body ceases to shine because its molecules when far away from the scene of the encounter pursue paths nearly parallel to the neighbouring ones, and molecular collisions become less and less frequent. The third body, which was a typical nova, fades away, and in its place the two slightly variable wounded stars remain.

THE SPECTRUM OF A NOVA.

The typical spectrum of a nova is exactly the spectrum which might be expected from the characteristics of a third body. If the colliding stars are dark, the nova spectrum is almost entirely due to this cosmic spark. If the stars are originally luminous, the great increase of light is still practically all due to the third body. The wounded suns cannot make their presence felt until this body has dissipated sufficiently to cease from hiding them in its dazzling brilliance.

At first the compression is so intense that the spectrum of the third body is continuous. Soon, however, the outrush causes an atmosphere of very varied constitution, all elements starting their outward journey jumbled promiscuously together in one vast flying crowd. The spectrum then is crossed by fine dark lines. As molecular interchange of energy takes place, the hydrogen and helium gradually reach the surface with high velocity and form an ensphering shell. The velocity of the hydrogen often exceeds 1,000 miles a second, and may have double that value. Since the hydrogen is rushing outwards in all directions, the bright lines which it gives

will be widened into bands. The bright nucleus will shine through that portion of the sphere of hydrogen directly between it and our eyes—that is, through the portion that, coming directly towards us, has the greatest relative velocity of approach. Every bright band must therefore be bounded on its violet side by a dark absorption-band.

Since the velocity of the hydrogen is usually very far above the critical velocity of escape from the small third body, gravity can produce hardly any diminution of its speed. In fact, in the intensest parts of the gravitation field, gas-pressure exceeds gravitational attraction, and so, instead of retardation, the hydrogen shell experiences acceleration. The bright hydrogen bands on the spectrum therefore retain their full width until they finally fade away. As the violet edges of these bright bands are cut off by absorption, the centres of the bright bands appear slightly displaced towards the red. It was this fringing of the bright bands by dark absorption companions on the violet side which gave rise to the untenable suggestion that the spectrum was a composite one, due to a star with a dark-line spectrum rushing towards us with high velocity, and a star with a bright-line spectrum receding from us at a more moderate speed. Although it was pointed out in 1892 that the spectrum observed is the spectrum of the third body and not the spectrum of the colliding stars, the improbability of every nova being produced by a star showing an absorption spectrum rushing towards us and meeting a star with a bright-line spectrum going from us is used in 1924 by H. Spencer Jones in *General Astronomy* (p. 335) as an argument against the impact theory.

The difficulties vanish when it is realized that the typical nova spectrum is that of an intensely heated, thermodynamically unstable body in which equalization of temperature due to equipartition of energy has given speeds of the order of 1,000 miles a second to the lightest molecules, and that the intense radiation from this explosive mass completely hides the comparatively feeble light of the wounded stars.

There is no doubt that Jeans is right in saying that perfectly direct head-on collisions lead to a branch of cosmical evolution which does not seem likely to contain systems like our own. Such impacts appear to lead to pulsating stars of a peculiar type. But his suggestion that the branch line which diverges from the main line at the occurrence of a violent tidal encounter is the one in which we should look for the solar system does not seem so happy or so convincing. In making this suggestion, however, he has taken an astonishingly long step in the right direction. For forty-six years astronomers have refused to consider the phenomena resulting from an encounter of two stars, simply on the ground of inherent improbability. Jeans now attributes the origin of the solar system to a violent tidal encounter, which can hardly be distinguished from a partial impact. He does not say whether he considers the two stars to be equal or widely different in mass. To produce the desired effect it seems as if the disturber would have to be extraordinarily massive. But if they are equal, Jeans says, their centres must come within $2\frac{1}{4}$ radii of one another. When this occurs the tips of the inner tidal protuberances from the two stars are both within the region where what he calls the two critical spheres overlap. The tip of each tide is nearer to the centre of the disturbing star than to that of its own. The ends of the two tides occupy the same space and overlap. They have, in fact, collided—they are one. The case is not a mere close approach: it is a partial impact. The colliding tips form a new third body, which is left behind as the stars pass on. Its internal

energy is too great: it will be entirely dissipated. It is very doubtful whether any other portion of the inner tides can be permanently separated from one or other of the stars. To leave its own star during the critical time of close approach any matter would have to pass further within the critical sphere of the other, and would therefore in all probability be precipitated on to it, while that which did not pass the limit would be likely to return to its parent star.

But now that Jeans has suggested that to form our solar system two stars may have come so close to one another that, even if no tides were raised, their surfaces would be less than a quarter of a radius apart, surely he can no longer deny the possibility of a stellar collision. Now, although neither of the types so far considered seems likely to result in the formation of a sun with a family of planets, there is an intermediate type of encounter in which such a result seems not only possible but inevitable. This is the case in which the collision is by no means direct, but in which so large a fraction of each star lies in the path of the other that the complete escape of any considerable amount of matter from the combined system becomes impossible. This is the case which Bickerton calls "whirling coalescence." Jeans focuses attention on the inner tides, but the outer ones appear to be of much greater importance. The inner protuberances have no chance of developing much beyond the point pictured by Jeans when the centres of the two stars are $2\frac{1}{4}$ radii apart. The tips of the tides are just meeting. The encounter has begun. Changes are now astonishingly rapid. In half an hour the two stars are blended into one and the inner tides are smothered in the whirling mass.

We trust that in his next paper Jeans will discuss the history of the resulting system. It seems probable that it is something like this: The two stars meet with parabolic velocity, neglecting the effect of their original proper motions. If they had not met they would have passed away indefinitely into space. When the main portions meet and coalesce into a whirling mass the outer tidal protuberances are flung off. If the two stars are of approximately equal size but different density, the lighter will attain the greater velocity, and suffer the larger tides. The portions flung from the lighter star will be more massive and will start with higher speed. A moderate difference in density is sufficient to account for all the ejected matter from the light star being flung farther than any from the heavier. Each portion as it goes will suffer tidal distortion and be broken into a series of nuclei. The main portion of the material ejected will come from the tidal protuberances, and will for a time be distributed along two spiral arms. But all will not be flung quite simultaneously, and so the whole region of the plane of relative motion will be strewn with fragments moving initially in eccentric elliptic paths with their major axes in all azimuths. Selective molecular escape from the whirling mass within will soon fill the whole vast region with a dense gaseous atmosphere. The nuclei of the planets and satellites will start gathering up the scattered material. The accretion and the resistance of the gaseous medium will gradually reduce the eccentricity of the orbits, and precession of their equinoxes will aid them in collecting the scattered material. The Earth and Moon were probably flung off in one rotating mass, which tidal action lengthened out and separated before it proceeded far. The Moon's rotation and revolution were thus initially the same, and, although the Earth spun ever faster as it shrank, tidal friction prevented the Moon from ever deviating from this

relation. The ringed plains which scar its face bear striking testimony to the intense bombardment it suffered when its crust first formed, and whilst the liquid Earth was still unable to retain any evidence of the suffering by which it grew. The large families of planets surrounding Jupiter and Saturn are accounted for by the less consolidated state of the star from which they were flung, and the consequent more complete tidal disintegration.

On this view of the origin of the solar system the ecliptic is approximately the plane of relative motion of the encountering stars; the deviations of the axes of the Sun and planets from perpendicularity to this plane are due to the survival of some traces of the original rotations of the stars. The inequality of the rate of rotation of the Sun in different latitudes is but a trace of the greater inequality impressed on it during the whirling coalescence of the two bodies out of which it was formed.

Finally, from this point of view, is it necessary to consider the solar system as exceptional or out of the main line of evolutionary progress? If full account is taken of the abundance of non-luminous matter, collisions may not be nearly as rare as they are usually supposed to be. If stars owe their rejuvenescence to encounters, every star that is shining now must have met another again and again in the infinite ages of the past. The number of novae observed testifies to the fairly frequent occurrence of stellar grazes, and though whirling coalescence, or complete union of any kind, would not be noticeable enough to catch the observer's eye, every giant M star is a proof of the rythmic cyclic character of stellar evolution.

THE YALE TELESCOPE OFFER.

AN earlier number of this *Journal* (vol. iv, No. 2, 1921) contained an article by Dr. C. E. Adams, Government Astronomer, summarizing the history up to that time of the plan for establishing in New Zealand a 25 in. refracting telescope offered by Yale University for stellar research, in which Yale observers were to work, sharing the telescope with New Zealand astronomers. The present article, based largely upon the correspondence sent to and received from Yale, brings the account up to date.

The foundation of the plan was laid in 1915, during the time when Dr. Adams, as holder of the Martin Kellogg Fellowship in Astronomy, resided at the Lick Observatory; and the offer itselt, communicated in 1920, originated from Dr. Frank Schlesinger, Director of Yale Observatory. The offer, as set out in the article referred to, was "to provide a large photographic refracting telescope, the optical parts alone of which will cost £5,000. . . . With this great telescope Yale will send to New Zealand two American astronomers to undertake urgently required observations on the southern stars, and these gentlemen will use the telescope for about one-half of its available time. It is intended by Yale to leave this telescope permanently in New Zealand, provided that a satisfactory site can be obtained, and that New Zealand is prepared to assist. The assistance required from New Zealand would include land, foundations,

and building for the telescope, and offices and residences for the astronomers."

The value of the telescope alone was later estimated to be £9,000 or thereabouts, and the cost of the foundations, dome, and buildings (for which New Zealand is to pay) to be £4,200 as an absolute minimum, this being Yale's estimate, based on American costs.

Two definite offers to provide funds towards the cost of the work have been made. One was transmitted to Yale by the New Zealand Astronomical Society, which, through Sir F. R. Chapman, was tendered a gift of £5,000 by Mr. Horatio Massey. This gift was contingent upon the telescope being erected in the South Island. Another offer, of £3,000, was made by the Auckland City Council, a condition being that the telescope should be placed in Auckland City. In each case the gift was for capital expenditure only. The conditions of financial stringency which prevailed at that time and since were sufficient to prevent the Government from adding to this small embarrassment of riches, and, with so much to go upon, the most interesting question left was the selection of a locality for the observatory.

On the question of site, Professor Schlesinger wrote on the 16th October, 1920, as follows: ". . . Good seeing is the all-important object. Next, I should say, is the amount of clear weather; and high up in the list come the social conditions. With regard to the latter, my experience teaches me that it hampers any observatory needlessly to put men where they are deprived of the things that go to make life pleasant for the normal individual. I do not mean by this that the telescope need be placed near a great city, but that such things as concerts, books, theatres, and, above all, intellectual people should be within reach."

When the Yale offer was announced the Otago Astronomical Society commenced tests at a number of localities. Details of the results of these were reported by the Secretary of the Otago Society (Mr. J. C. Bell, F.R.A.S.) in a paper read before the Australasian Science Congress in 1923, and printed in the *Transactions* of that body. Dr. Adams visited the localities and recommended that telescopic tests should be undertaken in Otago. Tests with telescopes were made by private observers in Wellington, Nelson, and Otago; and so far as Wellington is concerned the results have been and are being published in detail by the New Zealand Astronomical Society.

In February, 1923, letters were sent by Professor Schlesinger to Dr. W. B. Benham (Curator of the Otago Museum), to Mr. T. F. Cheeseman (Curator of the Auckland Museum), and to Mr. R. Speight (Curator of the Canterbury Museum), relating to the necessity for co-operation to enable the telescope "to be used whenever the sky is clear, instead of merely half the time, as would be the case if the observations were confined to the very definite plan that Yale has in view."

As the New Zealand Astronomical Society, with whom Professor Schlesinger had hitherto corresponded, was not made aware directly of these communications, it wrote on the 4th June, 1923, emphasizing that the society had no special interest in setting up the observatory in one part of New Zealand rather than another, being only concerned that the best site should be chosen; and it suggested that the objects of Yale could be best furthered by utilizing the society as centre of communication and agent in obtaining the required assistance from the New Zealand Government or other bodies.

In September, 1923, it was reported from Auckland that a definite arrangement with Yale respecting the location of the telescope in that city had been made, and this report was confirmed by Dr. Schlesinger in a letter dated 1st October, 1923. His letter (with slight omissions) is as follows :—

Early this year, on the advice of my colleague, Professor H. E. Gregory, who is in charge of the Bishop Museum at Honolulu, and who is well acquainted in New Zealand, I wrote to both Dunedin and Auckland making to them substantially the same proposal with which you are familiar—namely, that Yale would agree to send a large photographic refractor and two observers to operate it for approximately half of every night if the New Zealand parties would agree to erect a suitable shelter, with the privilege of employing the other half of each night for whatever astronomical researches might be elected. To the Dunedin letter I received appreciative replies, but no definite acceptance. From Auckland, on the other hand, I received an acceptance, without reservation, of my proposal, and an agreement to provide the building as specified.

Naturally, both these offers are contingent upon finding a suitable site. Nothing seems to be known about the steadiness or definition at any point in New Zealand.* We have accordingly sent to Auckland an 8 in. telescope for the purpose of testing the seeing through several months. If Auckland should prove to be a suitable place for such an instrument as we are making we expect to locate there.

In the meantime we have gone ahead with our plans in other respects. The objective is now finished. It is a 26 in. of 36 ft. focal length. Mr. McDowell, who figured it, speaks of it in superlative terms. I expect to test it myself within a few days or few weeks. The mounting, too, is going forward as rapidly as we could hope. Unless something unforeseen prevents, we expect to complete it by next spring. It is being made, for the most part, in our own shops at the Observatory.

I should mention that we have received very generous offers of facilities, &c., from several points in South Africa where the seeing has been amply teste., and where the conditions are known to be very good indeed. If we do not go to Auckland we shall probably go to one of the sites in South Africa.

I deeply regret that circumstances are such as to limit our prospects for various sites in New Zealand, but I understand very well how unavoidable this has been. I realize that if we should wait another year with our plans matters might bear a very different aspect ; but this I am loath to do, as I am impatient to begin the work for which this telescope is principally intended.

I hope nothing in this situation will prevent you from being able to secure the funds necessary for testing the seeing at various places in New Zealand. Wholly aside from Yale plans, it seems to me that it would be a great pity to delay these tests any longer in view of their inexpensiveness as compared with the large results which may very possibly flow from them.

The story of the negotiations is completed by the fact that in 1923 the Government, impressed by the representations of a large deputation of Wellington astronomers and others, decided to grant £500 for the purpose of site-testing. The conclusion of the arrangement in respect to Auckland, however, resulted in the allocation being deferred. The 8 in. telescope mentioned in Dr. Schlesinger's letter duly arrived in Auckland, and testing proceeded. The results have been reported directly to Yale, and had not, at the time of writing, been published in New Zealand. The Auckland tests, however, appear to have shown that another site must be sought. Cabled advice was recently received by the Mayor of Auckland from the Yale University authorities, stating that the conditions did not meet the requirements for the work intended to be done. On the publication of a report to this effect, the New Zealand Astronomical Society renewed its activity in connection with the choice of a site, in the hope that a satisfactory place can be found in the Dominion.

Details of the Yale proposal and of the plan for working the telescope for the benefit of both Yale and New Zealand were supplied in a letter

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* The tests at Wellington had begun in July, 1923.

sent by Dr. Schlesinger to Dr. Jack, of Otago University, in 1922. It stated,—

Our telescope is to be of 25 in. or 26 in. aperture, and is to be of long focal length. Recent developments have proved that only such a telescope is capable of attacking efficiently certain problems that depend for their solution on the accurate measurement of star places. Most important of all in this respect comes the determination of the distances of stars, and next the determination of the motions of faint stars. There is no telescope in the Southern Hemisphere—or, indeed, outside of the North Temperate Zone—that is capable of undertaking such researches, and the telescope we have in view would therefore occupy a field by itself that would make it in certain important respects one of the most useful telescopes that astronomy has at its disposal.

The Yale Observatory has a definite programme to carry out in the Southern Hemisphere, a programme that would require the use of only approximately half the time of the telescope. It has therefore occurred to us that it would be advantageous from every point of view if some plan of co-operation could be carried out that would enable this valuable telescope to be used whenever the sky is clear, instead of merely half the time.

The Yale Observatory intends to spend at least £9,000 on this undertaking. This would include a telescope complete, and such auxiliary apparatus as may be necessary for the work that we have in view. We should expect to send with the telescope two observers, with measuring-engine, computing-machine, and whatever other apparatus may be necessary to complete this work. Our proposal is that the co-operating parties in the Southern Hemisphere shall erect a suitable building in which to house this telescope, and shall have the use of the telescope for approximately half the time.

Such a building would consist of a hemispherical dome built of wood, and 40 ft. in diameter, supported upon a cylindrical enclosure about 25 ft. high. Leading into this enclosure there should be at least two rooms: a small study and sleeping-room, and a photographic dark-room for developing plates and so forth. These are the minimum requirements. From the point of view of the community in which the telescope is to be placed, I would strongly urge a lecture-room capable of holding at least fifty people, and provided with a collection of lantern-slides (which would cost not more than £40) and a simple projection lantern (not over £10). I should mention in this connection that we expect to fit the telescope with a device that would transform it into a visual telescope so that it can be used for ordinary eye observations, including the delightful occupation known as star-gazing.

It is necessary that electric lights and running water should be available in the observatory; and there should be some means of heating the study, the dark-room, and the lecture-room, but not that part of the building in which the telescope is erected.

It is extremely difficult at this distance to say what the cost of such a building would be. If we were erecting one here (where I am familiar with conditions) I should say that £4,200 would be the very minimum, and that if the co-operating parties were willing to lay down dollar for dollar with us a building adequate in every way, both from the aesthetic and utilitarian point of view, would be possible.

The share of the work of the telescope to be carried out by the co-operating parties would require one or two observers, depending upon the nature of the work. For example, if the discovery and measurement of double stars were undertaken (and this is also a very pressing need in the southern skies) a single observer would be able to handle the work. On the other hand, if spectroscopic observations were undertaken two observers would be required.

Dual control of any organization is always risky, but can be carried out if the contracting parties set down a very definite agreement. This we should be prepared to do when the proper time comes to discuss details. Both parties should recognize from the beginning that such an agreement calls for the exercise of more than the usual amount of diplomacy and patience. It is especially desirable that one person of those who are using the telescope should be specifically designated as being in charge. The logical thing to do is to choose for such designation the person who has the most experience, and Yale Observatory would be quite willing that this should be a local man if he fulfils this condition.

Naturally both parties to this agreement would wish to stipulate a minimum period during which this agreement should be in force, and this period must not be too short. I would suggest that an agreement lasting ten years would be about right, with the understanding that at the expiration of this period we shall discuss a new arrangement for its renewal, and that the agreement shall set down the terms under which either party may acquire at the termination of each ten-year period the interests of the other, if they wish to do so.

A REPORT ON MEAT MOULDS.

Mould Growths upon Cold-store Meat, by F. T. Brooks and C. G. Hansford, *Dept. Sci. Ind. Res., Food Invest. Board*, Special Report No. 17. 36 pp., 10 text-figs. 1923.—Both during and after the war, in England, meat held for long periods in cold storage frequently became affected with various moulds, which caused unsightly blotches and spots to appear externally on the exposed parts. It occurred occasionally in New Zealand also during the war period.

In this report the authors have recorded the results of their researches, commenced in 1918, into the cause, economic effect, and methods of prevention of these moulds. Their investigations were confined to meats held in cold storage in England, received from New Zealand, Australia, and the Argentine. No less than eleven species of fungi were found to be the causal agents, the appearance of the disfiguration differing according to the specific organism concerned. It would appear that all these fungi, with one exception, were frequently encountered on meat from all the exporting countries, thus showing their widespread nature.

In the meat trade moulds are grouped according to their appearance on the substrata, and are known by the names (*a*) black-spot, (*b*) white-moulds, (*c*) blue-moulds, (*d*) yeasts, and (*e*) whiskers, respectively.

(*a.*) *Black-spot.*—This disfiguration is due to the fungus *Cladosporium herbarum*. Small black spots 6–12 mm. in diameter are produced on the "skin" overlying muscle and fat, especially on the skirt and pleura of beef, and on legs and the interior of the thorax of mutton. The spot penetrates no more than 4 mm. The colour is due to the dark hyphal masses which ramify in the superficial layers of the meat.

(*b.*) *White-mould.*—This condition is due to two species, *Sporotrichum carnis* n. sp. and *Torula botryoides* n. sp. They form small wooolly spots closely appressed to the surface of the meat, and, being superficial, may readily be removed with a cloth. A third organism, isolated from the surface of skinned Australian rabbits, proved to belong to a new genus. This organism has been named *Wardomyces anomala* n. gen. et n. sp.

(*c.*) *Blue-moulds.*—Two species of *Penicillium*, *P. expansum* Thom. and *P. asperulum* Bainier, were found to be responsible for this condition. Blue-green irregular discolorations are produced on the surface of the meat. These are entirely superficial, and may be removed with a cloth.

(*d.*) *Yeasts.*—These organisms produce minute semi-translucent white or pink spots on the surface of the meat. The white colony when dried forms a brown spot, which the authors consider is the same condition as that described by previous workers.

(*e.*) *Whiskers.*—This rather inappropriate term is applied by workers in the meat trade to mould-growths of 25 mm. or more in length which frequently occur on stored meat. Five species are associated with this condition—*Thamnidium elegans*, *T. chaetocladioides*, *Mucor mucedo*, *M. lusitanicus*, and *M. racemosus*. These growths also are entirely superficial, and may be removed with a cloth.

As a result of their cultural studies, in which these organisms were grown artificially at controlled temperatures, the authors believe that all but one of these fungi become prevalent only when the temperature of the store is allowed to rise to within the vicinity of freezing-point. Another factor which induces growth is that of humidity, for, where it is high, favourable conditions for their development are produced.

They state that these moulds do not confer poisonous properties on the meat, and, unless associated with putrefactive bacteria, do not render the

meat unfit for food. All, with the exception of black-spot, may be removed with a cloth, for they are superficial, or almost so.

The black-spot lesions penetrate to a depth of 4 mm., and may be removed by trimming away the discoloured parts.

The authors state that by controlling temperature and humidity conditions in the cold stores, and by avoiding unduly prolonged storage, the growth of these fungi can be prevented.

Morphological and cultural characters of all the species under discussion are given, together with drawings and diagnosis of three new species. A bibliography of eighteen titles is appended.

G. H. C.

A NEW ZEALAND STUDY IN SEX DELINQUENCY.

By E. P. Neale, D.Sc., M.Com., LL.B., F.S.S., &c.

Statistics of illegitimate births are available for New Zealand as far back as 1873, but there is good reason for the belief that prior to 1876 many illegitimate births were registered as legitimate. In the latter year a new Registration Act came into force, providing that the date and place of marriage of the parents of all children born should be supplied in connection with birth-registrations: this abolished the practice whereby mothers of illegitimate children had been registering them as the offspring of fictitious husbands. It is quite possible, however, that illegitimacy is still underestimated in the statistics, despite a stringent law rigorously enforced; in particular there must exist cases where the illegitimate issue of married women are registered in the names of the mothers' husbands, and other cases, possibly, where the illegitimate offspring of young single girls are officially recorded as the legitimate offspring of the ladies who are in fact the infants' maternal grandmothers. Similarly, prior to 1920 the illegitimate children of divorced women were probably for the most part registered as the offspring of the former husbands, whether in fact such husbands were or were not the fathers: by the passing of the Marriage Amendment Act of 1920 the Registrar-General was enjoined to enter particulars of all divorces granted upon the corresponding marriage records, thus providing a check upon this practice.

Table No. 1 shows the number of children born annually on the average during several years in relation to the number of women of reproductive age (taken for practical purposes as being 15 and under 45 last birthday) returned in the nearest census. Averaging four or five years is of advantage, because it eliminates fortuitous casual variations in the number of births in any particular year. Legitimate children are also considered in this table in relation to married women of child-bearing age, and illegitimate children in relation to unmarried (*i.e.*, widowed, divorced, and never married) women of similar ages. It is quite certain, of course, that maternity has different frequencies for (*a*) the never married, (*b*) the widowed, and (*c*) the divorced; no statistic is, however, available in New Zealand whereby this could be allowed for. The table affords conclusive evidence of a progressive decline, not only in the rate of legitimate, but also in the rate of illegitimate, births. Legitimate rates have, however, been declining much more rapidly than illegitimate rates, a fact which is well brought out by Table No. 2, which shows year by year since 1876 the total number of illegitimates born, together with the proportion of illegitimates among total children born. The latter figure increased rapidly till 1895, after which it has remained at a fairly constant level.

TABLE NO. 1.—ANNUAL FECUNDITY RATES FOR (*a*) TOTAL FEMALE POPULATION, (*b*) TOTAL MARRIED FEMALE POPULATION, AND (*c*) TOTAL UNMARRIED FEMALE POPULATION OF MARRIAGEABLE AGE (15 AND UNDER 45 LAST BIRTHDAY).

Average of Years.	Children born per 1,000 Women of Reproductive Age.	Legitimate Children born per 1,000 Wives of Reproductive Age.	Illegitimate Children born per 1,000 Unmarried Women of Reproductive Age.
1876–79 ..	214·4	330·0	13·3
1880–83 ..	198·4	322·8	13·5
1884–88 ..	164·3	299·4	10·9
1889–93 ..	138·7	278·5	9·2
1894–98 ..	118·0	256·1	9·0
1899–1903 ..	110·5	243·7	8·8
1904–08 ..	114·5	236·7	9·6
1909–13 ..	111·6	215·3	9·6
1914–18 ..	103·9	188·0	9·4
1919–22 ..	97·0	177·6	9·1

TABLE NO. 2.—ILLEGITIMATES BORN, AND PROPORTION TO TOTAL CHILDREN BORN, EACH YEAR 1876 TO 1922.

Year.	Illegitimates born.		Year.	Illegitimates born.	
	Total.	Per Cent. to Total Children born.		Total.	Per Cent. to Total Children born.
1876 ..	361	2·23	1900 ..	906	4·63
1877 ..	351	2·08	1901 ..	937	4·57
1878 ..	429	2·41	1902 ..	921	4·46
1879 ..	415	2·30	1903 ..	994	4·55
1880 ..	471	2·43	1904 ..	1,029	4·52
1881 ..	534	2·85	1905 ..	1,082	4·57
1882 ..	546	2·87	1906 ..	1,132	4·67
1883 ..	534	2·78	1907 ..	1,157	4·61
1884 ..	587	2·95	1908 ..	1,105	4·26
1885 ..	630	3·20	1909 ..	1,223	4·61
1886 ..	602	3·12	1910 ..	1,162	4·47
1887 ..	617	3·23	1911 ..	1,078	4·09
1888 ..	577	3·05	1912 ..	1,177	4·28
1889 ..	612	3·32	1913 ..	1,181	4·23
1890 ..	603	3·30	1914 ..	1,302	4·59
1891 ..	638	3·49	1915 ..	1,152	4·14
1892 ..	593	3·32	1916 ..	1,146	4·10
1893 ..	673	3·70	1917 ..	1,159	4·56
1894 ..	704	3·80	1918 ..	1,179	4·65
1895 ..	835	4·50	1919 ..	1,138	4·65
1896 ..	834	4·48	1920 ..	1,424	4·76
1897 ..	826	4·41	1921 ..	1,258	4·44
1898 ..	801	4·23	1922 ..	1,224	4·22
1899 ..	829	4·40			

TABLE NO. 3.—FIRST BIRTHS IN RELATION TO DURATIONS OF MARRIAGES: TOTAL OF YEARS 1913 TO 1922.

Mothers' Ages in Years Last Birthday.	Illegitimates.	Legitimates: Durations of Mothers' Marriages in Months.												Total Legitimate under One Year.	Total Legitimate First Births.
		Under 1.	1 and under 2	2 and under 3	3 and under 4.	4 and under 5.	5 and under 6.	6 and under 7.	7 and under 8.	8 and under 9.	9 and under 10.	10 and under 11.	11 and under 12.		
12 ..	2	..	..	..	..	..	..	..	..	..	..	..	..	..	..
13 ..	6	..	..	..	..	..	..	..	..	..	..	..	..	..	..
14 ..	28	..	..	1	..	..	..	..	..	..	..	..	..	1	1
15 ..	121	..	1	6	3	2	..	2	..	1	..	..	..	15	15
16 ..	256	9	7	16	13	19	13	15	8	1	3	1	1	106	112
17 ..	581	38	46	46	68	64	66	56	37	19	29	11	10	490	517
18 ..	875	51	77	109	144	181	184	200	108	69	65	50	44	1,282	1,439
19 ..	1,092	63	98	170	233	234	275	335	219	125	180	160	112	2,204	2,691
20 ..	1,092	78	120	166	215	260	331	375	274	200	317	255	207	2,798	3,710
21 ..	1,040	83	143	162	266	279	403	458	326	310	516	382	312	3,640	5,131
22 ..	896	72	106	144	203	241	341	424	377	390	699	621	492	4,110	6,547
23 ..	820	70	86	108	178	196	279	320	305	338	763	643	454	3,740	6,654
24 ..	658	37	66	77	124	156	233	318	260	303	747	603	463	3,387	6,595
25–29 ..	2,287	126	179	249	347	424	563	773	704	950	2,626	2,232	1,718	10,891	26,710
30–34 ..	1,225	45	58	94	104	107	148	223	233	338	963	872	667	3,852	12,779
35–39 ..	751	12	34	31	41	50	48	81	97	104	261	213	219	1,191	5,208
40–44 ..	273	5	11	12	13	14	15	16	14	22	29	40	30	221	1,257
45 and over..	18	..	..	..	1	2	2	1	..	..	2	3	5	16	108
Not stated ..	19	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	12,040	689	1,032	1,391	1,953	2,229	2,901	3,597	2,962	3,170	7,200	6,086	4,734	37,944	79,474

TABLE NO. 4.—PERCENTAGE OF "PREJUDICED" BIRTHS TO SUM OF ILLEGITIMATE BIRTHS AND LEGITIMATE FIRST BIRTHS.

Mothers' Ages in Years Last Birthday.	Total of Illegitimate Births plus		Percentage of "Prejudiced" Cases to Sum of Illegitimates and Legitimate First Births.
	All Legitimate First Births.	Legitimate First Births within Nine Months of Marriage.	
	(a.) 1915–1917.		
13 ..	..	1	100
14 ..	1	7	100
15 ..	42	42	100
16 ..	89	86	97
17 ..	322	295	91
18 ..	659	556	84
19 ..	1,115	823	74
20 ..	1,432	895	62
21 ..	1,737	876	50
22 ..	2,141	870	41
23 ..	2,085	725	35
24 ..	2,053	616	30
25–29 ..	8,255	1,818	22
30–34 ..	4,728	709	15
35–39 ..	1,534	363	23
40–44 ..	342	107	31
45 and over	25	6	24
Totals ..	25,586*	8,914*	35
	(b.) 1920–1922.		
12 ..	2	2	100
13 ..	4	4	100
14 ..	8	8	100
15 ..	42	42	100
16 ..	111	111	100
17 ..	364	341	93
18 ..	727	637	88
19 ..	1,261	975	77
20 ..	1,612	1,059	66
21 ..	2,172	1,232	57
22 ..	2,566	1,135	44
23 ..	2,680	940	35
24 ..	2,563	748	29
25–29 ..	10,047	2,310	23
30–34 ..	4,609	910	20
35–39 ..	1,765	407	23
40–44 ..	462	131	28
45 and over	33	8	24
Totals ..	31,028	11,000	35

* Includes 19 with ages unspecified.

Since 1915 data have been available in New Zealand whereby it is possible to consider the fecundity of unmarried women by age-groups. Averaging the years 1915 to 1917, we find an annual illegitimate birth rate of 6·2 per 1,000 unmarried women 15 and under 20 last birthday; the corresponding figures for other age-groups being: 20 and under 25—13·2; 25 and under 30—11·5; 30 and under 35—9·4; 35 and under 40—7·5; 40 and under 45—3·4: total for unmarried women 15 and under 45—9·4.

Closely allied to the study of illegitimacy by reason of the light it sheds on sexual delinquency is the study of first births in relation to duration of marriages. Sir George Knibbs, at pages 276 to 278 of his *Mathematical Theory of Population*, has exhaustively considered the evidence available as to the period of human gestation. He shows that, contrary to popular opinion, this period has a considerable range, varying from seven to eleven months. In the majority of cases, however, the period approximates very closely to the arithmetical average; cases above and below the average are, moreover, approximately equal in number. He concludes that it is a satisfactory rule to count births occurring less than nine months from marriage as being the result of pre-marital intercourse; those occurring more than nine months from marriage the result of post-marital intercourse. In any individual case this assumption is not necessarily valid, but in the aggregate it is, since negative divergences and positive divergences from the normal period balance each other.

Table No. 3 shows first births in relation to the ages of mothers and the durations of their marriages from 1913 to 1922. The great popularity of six months revealed by the table may be definitely attributed to the fact that from two to three months will usually elapse between fruitful intercourse and the date when a marriage can be arranged when once the fact that conception has occurred has been established beyond doubt.

Table No. 4 shows, (*a*) for the years 1915–17, (*b*) for the years 1920–22, the percentage of births "prejudiced" by extra-marital conception to the total of illegitimate births plus legitimate first births. Of 167 first children born during the years 1920 to 1922 to mothers under 17 last birthday, 122 were illegitimate and 45 were born in wedlock less than nine months after marriage, and therefore apparently conceived before marriage. There were *no* cases of children being born in wedlock to mothers under 17 last birthday nine months or more after marriage. It follows that the first offspring of mothers under 17 show 100 per cent. of "prejudiced" cases. The suggestion of the figures is that no marriages were other than "compulsory" which resulted in the birth of a child to a mother under 17. The proportion of "prejudiced" cases falls gradually with increasing age. For this the explanation lies no doubt partly in the increasing discretion that comes with maturer years, partly in increasing knowledge of the so-called neo-Malthusian practices (contraception, abortion, &c.). When the present-day spread of knowledge of such practices at all ages (referred to so forcibly by the 1921 New Zealand Commission on Maternity Mortality) is considered, the import of these figures (for example, that of every 100 women who became mothers for the first time under 21 years during the years 1915 to 1917 as many as 74 either bore illegitimate children or married in haste for respectability's sake, and that this figure had by 1920 to 1922 increased to 77) is little short of appalling. Despite our enlightened legislation, which has done much to improve the status of the illegitimate child, he lacks the moral and economic advantages of a father's influence and care. His disadvantages do not end here. The

unmarried mother is rarely in a position to give as much attention to the needs of her offspring as her married sister can give to hers; and this is glaringly reflected in the statistics of infantile mortality. Of the 1,215 infants who died in 1922 before the completion of their first year of life, 86, or 7·08 per cent., were illegitimate. This percentage is well over half as high again as that of illegitimate births to total births (see Table No. 2). Nor does the matter end even here. During the years 1914 to 1920 the average percentage of still-births to living births was: For mothers under 20—legitimate, 1·9; illegitimate, 3·5: for mothers 20 and under 25—legitimate, 1·9; illegitimate, 2·9: for mothers 25 and under 30—legitimate, 2·2; illegitimate, 3·0: for mothers 30 and under 35—legitimate, 2·5; illegitimate, 3·4: for mothers 35 and under 40—legitimate, 3·3; illegitimate, 4·8: and for all mothers—legitimate, 2·6; illegitimate, 3·2. Still-births are thus seen to be relatively much more frequent out of than within wedlock. This may be directly attributed to the fact that pregnant single women normally remain at their occupations up to the time of their confinement, or nearly so, often concealing their condition from those with whom they come in contact; married women, on the other hand, receive greater care, and are for the most part in a position to adopt a regimen of health suitable to their condition. The extreme youth (see Table No. 3) of many of the mothers under 20 of illegitimate children, unfitting them physiologically as it does for child-bearing, is probably responsible for the abnormally high proportion of still-births amongst unmarried girls (they can scarcely be described as women) at those ages.

There may conceivably be some doubt as to whether illegitimacy is or is not morally bad; but there can be no doubt that it is socially and economically bad, at least under present-day conditions. Anything that will reduce the amount of illegitimacy is therefore to be welcomed. Experience in the United States has shown that, while not all mothers in "prejudiced" cases are of a low order of intelligence, there are a surprisingly large number of high-grade defective girls ("morons") who pass through schools without being recognized as such.* With the weak inhibitive powers of a child of nine and all the instincts of a budding adolescent, such a moron, unless under vigilant supervision on the part of friends or relations, will almost inevitably fall a victim to the passing whims of the first plausible man or youth who crosses her path. The recent introduction of intelligence tests in New Zealand schools should enable these morons to be recognized and placed under supervision, thus at one stroke reducing sex delinquency and preventing the reproduction of undesirable types. The whole problem of sex delinquency is, however, a much wider one than this, and no plausible solution to the broader issues is in sight.

* See TERMAN: *The Measurement of Intelligence* (Houghton, Mifflin), 1916.

THE *UTU PIHARAU*, OR LAMPREY-WEIR, AS CONSTRUCTED ON THE WHANGANUI RIVER.

By ELSDON BEST.

So apt are the Aotea folk to drop the aspirate that to this day I am not sure whether the above term should be given as *utu* or *hutu*. Williams's Maori Dictionary gives "*hutu*, a fishing-net made of flax"; but then our *utu* is not a net, but a weir. The form of weir employed by Whanganui River natives was possibly confined to that district, or to the Aotea district. It has not, I believe, been recorded from other areas. Wakefield mentions seeing an *utu* at Waitotara.

FIG. 1.—An *utu piharau*, or lamprey-weir, at Hiruharama, Whanganui River, 1921. Te Kehu and Tau Tamakehu at work.

Weirs for eels and lampreys are constructed on different principles, for very good reasons well known to the natives. Eels are taken as they are moving down-stream, and when so migrating they keep out in the stream. On the other hand, lampreys are taken when they are moving up the river, and in doing so they hug the banks, doubtless to avoid the stronger current in mid-stream. Hence, as a natural sequence, eel-weirs are constructed in mid-stream, and lamprey-weirs near the banks. Another difference is that, in this river, eel-weirs are built so as to be set at but a slight angle to the current—such is the *pa auroa* form of the *pa tuna* (eel-weir); while lamprey-weirs are erected at right angles to the flow of the stream. The V-shaped form of eel-weir, common elsewhere, is not employed in the Whanganui River. The *pa auroa* has been minutely described in an excellent

and comprehensive paper by Mr. T. W. Downes. (See *Transactions of the N.Z. Institute*, vol. 50, p. 296.)

The photographs here reproduced were taken at Hiruharama, on the Whanganui River, in 1921, the weir being then in course of construction. The length of the fence-like structure was 35 ft., and it extended out from the bank at right angles to intercept the *piharau* (lamprey) in its up-stream course. The mainstay of the weir consists of a series of posts or heavy stakes of *manuka* driven vertically into the hard-packed river-bed, consisting of stones and gravel. These uprights, termed *pou*, are about 4 in. in diameter, are placed 3 ft. to 4 ft. apart, and are about 5 ft. high. On the down-stream side of these uprights are lashed two series of *manuka* rails (*huahua*), about 4 in. in thickness; thus we have a two-railed fence. All

FIG. 2.—Lamprey-weir. The old native *ta*, or maul.

the timbers are white *manuka*, which provides long, straight poles of great strength. This is *Leptospermum ericoides*.

All posts, stakes, and pegs used in the construction of the weir have been laboriously driven in by means of heavy punching with remarkably heavy mauls (*ta*). These are hewn out of heavy and cross-grained hardwood (*rata* in this case), and are the form of maul used in pre-European days. A hollow has been gouged out in the face of each, and it is this part that receives the end of the post when struck. The post is less liable to split than when struck by a flat-faced beetle. These implements are clearly depicted in fig. 2.

In order to render the weir-fence impassable to the lampreys save at the *ngutu*, or openings where they are trapped, lengths of *manuka* are inserted vertically between the posts, these poles being about 2 in. in diameter. Some *manuka* brush is also secured here so as to block openings through which the lampreys might pass. At the same time the fabric allows a considerable amount of water to pass through, which serves to

lessen the strain on the weir. A third rail is often added to support the projecting upper ends of the vertical intermediates.

Prior to the completion of the true fence, however, the supporting-struts are placed in position, and the scour-mat is laid down. All parts of the weir, be it observed, are lashed together in a very secure manner with split supplejack, a material of great strength, but not remarkable for durability. Such fabrics as fish-weirs are, of course, renovated every year.

There are two series of struts employed in bracing these weirs, in order that they may withstand the tremendous force of the rushing waters when the river is in spate. On the down-stream side heavy timbers are lashed in two rows or series; the upper series is lashed to the upper rail, and those of the lower series to the lower rail, their lower ends being inserted firmly

FIG. 3.—Lamprey-weir. Lashing top rail of fence with split *kareao*.

in the river-bed. These struts are termed *noko*. This double row of stout timbers is the mainstay of the entire fabric; they take the thrust of a huge flow of rushing water: on one occasion the writer saw 6 ft. of rolling waters flowing over that part of the river-bed. Strength is needed to enable a weir to stand up under such an assault.

On the upper side of the weir-fence are fixed backstay struts of lighter nature than the *noko*. These *kumekume*, as they are called, have one end lashed to the fence-posts about 3 ft. from the ground, while the other end, up-stream, is lashed to one of the firmly driven pegs securing the *whariki*, or scour-mat. Being firmly secured at both ends, these holding-braces assist in strengthening the fence. The name *kumekume* is derived from *kume* (to pull). In this case the scour-mat (*whariki* and *whakareinga*) extended some 25 ft. up-stream from the weir-fence, and about 6 ft. from it down-stream. In some weirs it extends much farther down-stream, the distance depending upon the likelihood of scour in the river-bed. The scour-mat itself consists of *manuka* brush of straight growth laid down on

the river-bed in a layer, as far out as the *kaiau*, or outermost post of the weir-fence. Across this mat of close-laid brush are laid several rows of poles, called in this connection *karapi*, which are pinned down by several series of crossed pegs driven firmly into the river-bed in the form of an X, so as to ride the *karapi*, the latter being also lashed to the pegs. In the 25 ft. *whariki* there are five series of these pegs to each *karapi*. In this weir the bottom rail of the weir-fence is about 18 in. above the *whariki*, and the upper rail about 3 ft. above the lower one. The brush worked into the fence is called the *pawai*.

In this weir are five *ngutu*, or openings, as seen in the illustration of the completed weir. It is at these openings that the nets and pots are set in which the lampreys are caught.

FIG. 4.—Old Te Kehu working at lamprey-weir.

We will now endeavour to catch some of those *piharau*, a dish highly prized by the gourmands of Te Awa nui a Rua. In setting pots to take eels coming down-stream we have a simple task to perform. To catch the lamprey going up-stream is by no means so easy. We cannot set pot and net on the upper side of the weir facing down-stream; several natural laws interfere with such a method. These appurtenances must be set facing up-stream, the direction in which the fish is travelling. How is the wily *piharau* to be persuaded to turn back on his course and enter the trap? Parawhenua, the daughter of the sun-god Tane, she who personifies the flowing waters, will attend to that.

It will readily be seen that, blocked by the *pawai* of the weir, the baffled waters of a freshet surge through the *ngutu* openings with much force. It is this rush of swift waters that serves to trap the lampreys. In this wise: A little distance below and immediately opposite to the opening, two stout stakes are driven firmly into the river-bed in an upright position. These are represented by BB in the diagram, while A is the *ngutu*, or opening in the

weir. The *poha*, or guiding-net, is a funnel-shaped net, the mouth of which is distended by a stout hoop to which it is secured. This hoop is secured to the upright stakes, the small end being down-stream (see C on diagram). The *hinaki*, or trap-pot, is secured to the lower end of the guiding-net, and is marked D. The small lower end of the net is placed within the conical entrance of the pot, and so any fish passing through the net must enter the pot trap. Now, when the lampreys encounter the weir-fence they seek a place to pass through it and so continue their way up-stream. Coming to a *ngutu*, they endeavour to pass up through it, but the strong rush of water throws them back and forces them down the funnel net into the waiting pot trap. From this place there is no return to the world of life; the life-history of the trapped lamprey ends with great abruptness.

The *hinaki*, or pot traps, employed in taking lampreys are not so large as the majority of eel-pots. In the Whanganui district they are made of

[*T. W. Downes, photo.*

FIG. 5.—*Utu piharau:* weir for taking lamprey or *tuna* at Parikino, Whanganui River. Looking up-stream.

the long, tough, and durable *aka kiekie*, or aerial rootlets of the *kiekie*, a forest climbing-plant (*Freycinetia Banksii*). These slim, pliant roots are stripped of their outer bark covering by being drawn through between the tightly compressed halves of a split supplejack (*Rhipogonum scandens*). They are then split down the middle with marvellous exactitude. Two of these lamprey-pots measured were 28 in. in length. The *whiti*, or hoops that form the body of these trap-pots, are pliant stems of climbing or creeping plants, notably those of *aka-tea* (*Metrosideros scandens*) and *aka torotoro*.

Fig. 1 shows Te Kehu, an old native of Hiruharama, driving the *pou* down with his heavy maul; Tau Tamakehu has delivered his blow and seems disinclined to strike another; while Mr. Chadwick, on the left, is earnestly warning them not to move. The lower rail has been attached, the *whariki* has been laid down, and some large stones placed on it. Fig. 2 shows the form of maul employed. Fig. 3 shows the two operators lashing

rail and strut; while fig. 4 shows Te Kehu attaching the upper rail towards the outer end of the weir, also the scour-mat. The first freshet that brings the lampreys up-stream and the *tuna-heke* eel down-stream will flow over

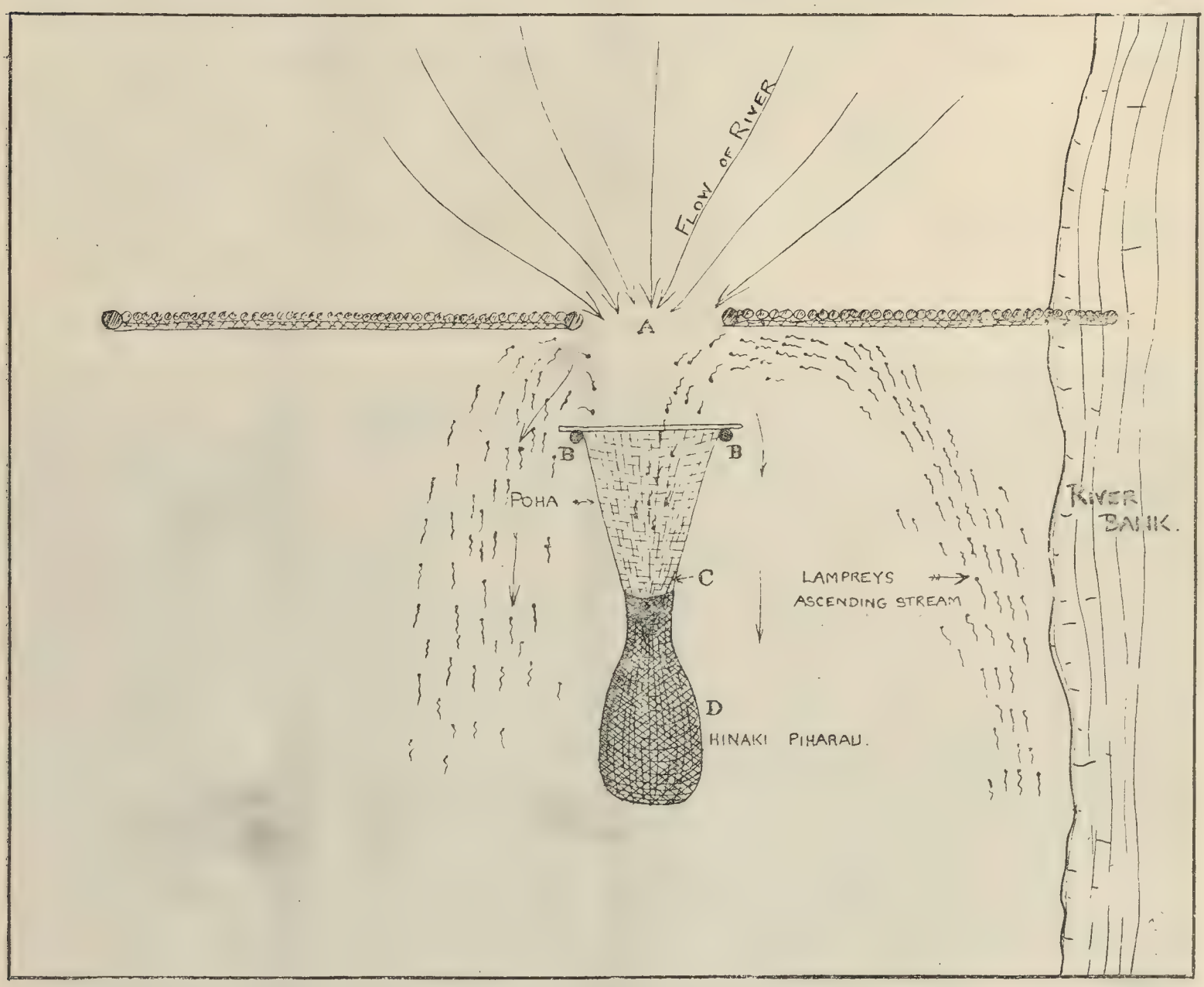

FIG. 6.—Diagram showing position in stream of *utu piharau*, or lamprey-trap.

the weir-site, now free of water. In fig. 5 we have a completed lamprey-weir at Parikino, Whanganui River, as photographed by Mr. T. W. Downes. It shows the down-stream side of the weir, and the heavy strut braces; the trap-openings and scour-mat are also clearly seen.

RECONSTRUCTION OF A MAORI CARVED STORE-HOUSE ON PILES (PATAKA).

By H. D. SKINNER, Assistant Curator, Otago University Museum.

IN January, 1921, the Maori carved house represented by fig. 1 was purchased for the Otago University Museum from the Denton estate, Wellington. It was stated to have been purchased by the late Mr. Denton many years ago in the district between Tauranga and Rotorua.

It is not known whether the outer carved posts and barge-boards had been carved and erected for an actual dwellinghouse, but they must have

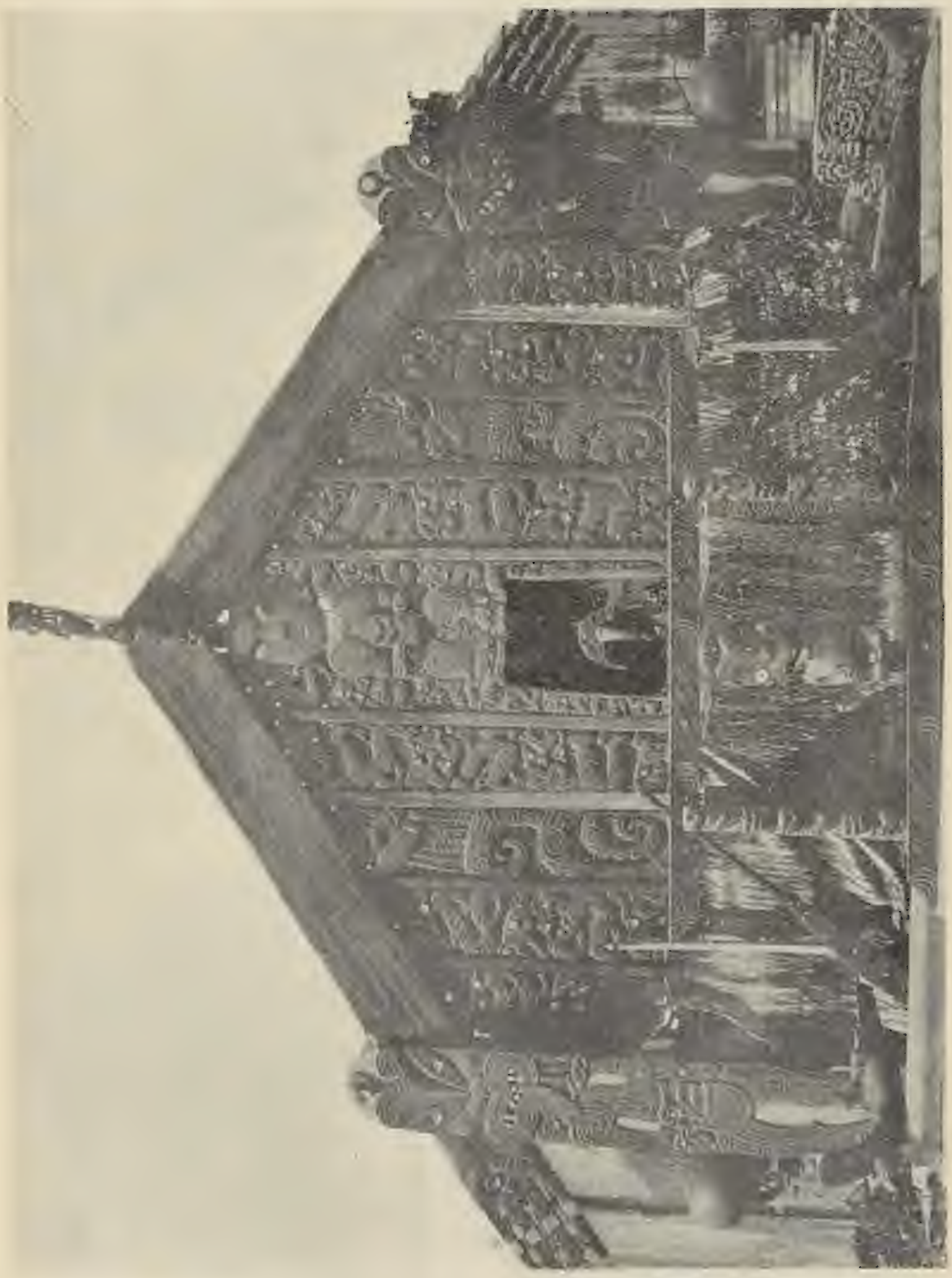

FIG. 1.

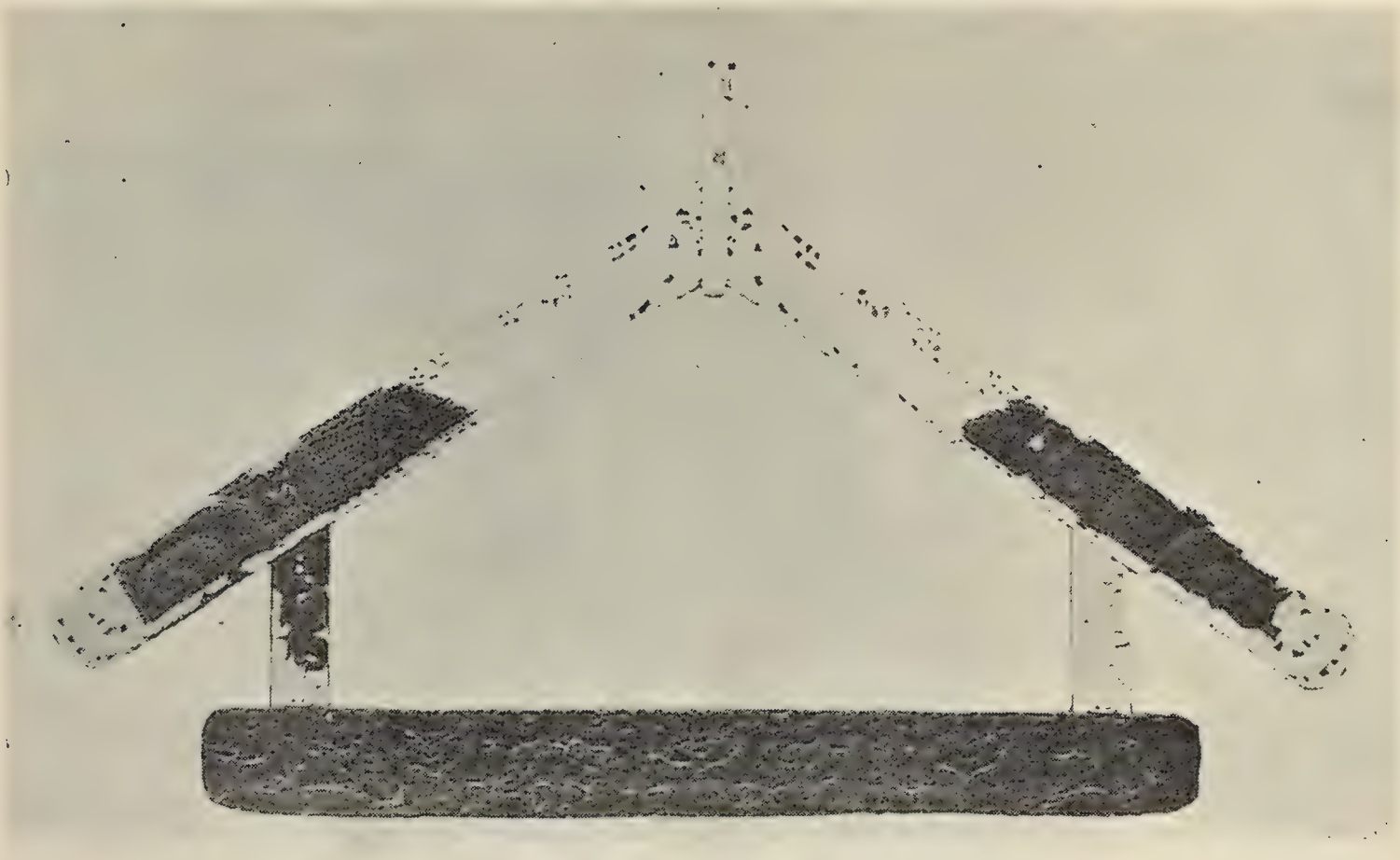

FIG. 2.

FIG. 3.

been already in existence when the exceptionally fine carvings from an old *pataka* were cut up and fitted in to them. The fine gable-end carving shown in fig. 1 belonged to the *pataka;* unfortunately it had been sold separately before the Otago University Museum made its purchase.

The problem which faced the purchasers was the restoration of the ancient *pataka.* The first step was to store the carved posts and barge-boards of the dwellinghouse, and to have a reproduction made of the gable-end carving. For the latter work Mr. K. Kania, who had previously carried out some excellent restoration work at the Museum, was employed. The next step was to secure for the front of the *pataka* a carved horizontal beam* and part of a carved post from the Hocken collection. These are

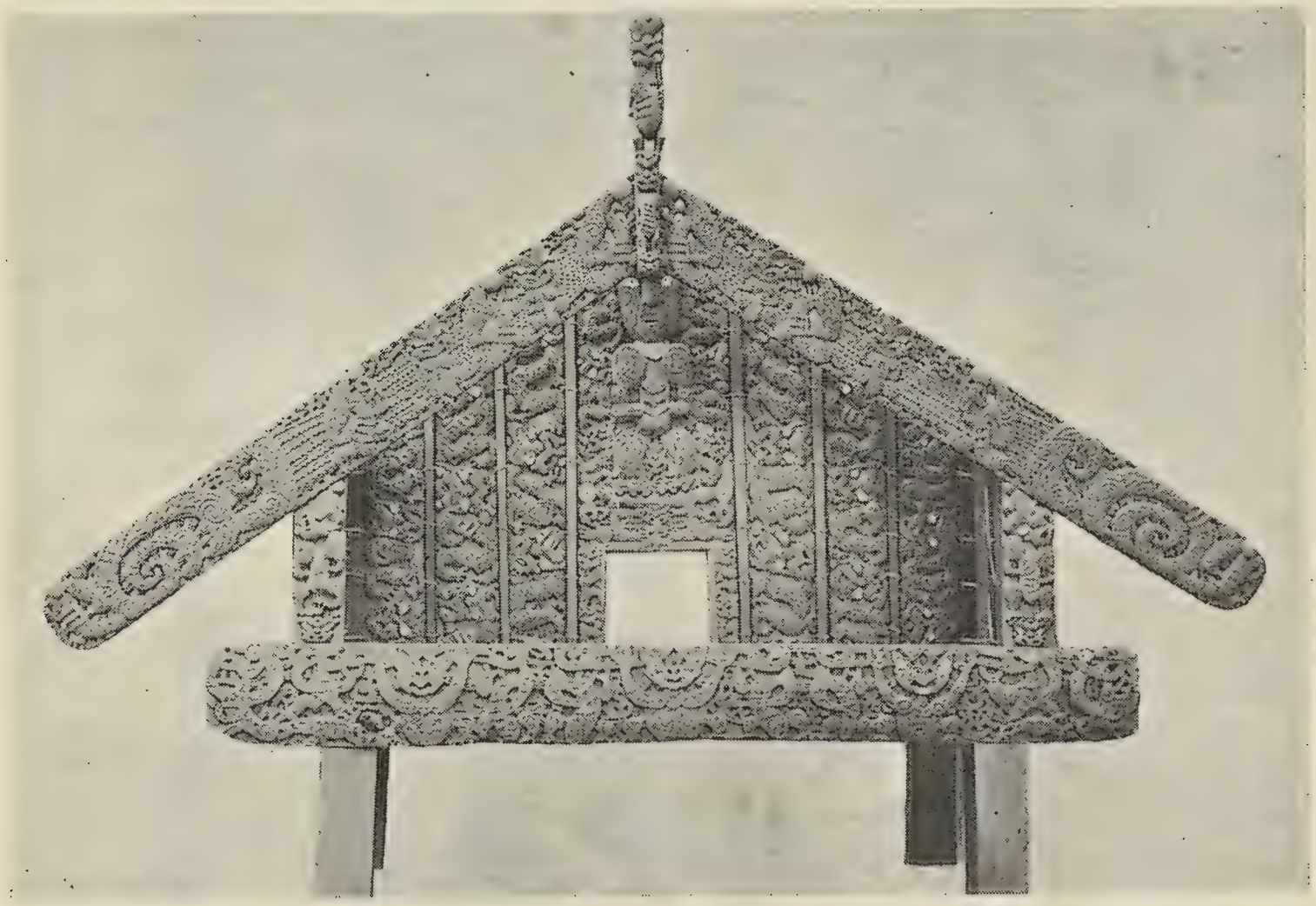

FIG. 4.

shown in fig. 2, in which, as in the two following figures, the new parts carved by Mr. Kania, have been whitewashed. The small carved post was restored as shown, and a corresponding post was carved for the opposite side. The restoration of the barge-boards presented a number of difficulties. The thanks of the Otago University Museum are due to the Curators of the Canterbury Museum, the Dominion Museum, and the Auckland Museum, who generously supplied photographs of *pataka* carvings in their collections, thus making possible a solution of some of the difficulties. The terminal figure which was destroyed in both barge-boards had necessarily to be a *manaia* (bird-headed man), and its general character was determined by the *manaia* in the right-hand barge-board, the head of which was quite plain: it has been whitewashed by mistake. In the left-hand barge-board were preserved three fingers grasping the "snake," a feature found in only one other *pataka* carving, that figured in *Bulletin 5*

* This *paepae* is figured by Mr. Best in *Dominion Museum Bulletin 5*, fig. 6.

(fig. 2, left-hand board). This splendid old piece was therefore followed as closely as possible. The spacing of figures, however, was very different, being determined by a small piece of the leg of the figure next to the *manaia* preserved in the right-hand beam. The remaining space was occupied by three figures in attitudes determined by the figures in the ancient barge-board, but all the details of the treatment were determined by the general methods of the Denton *pataka* itself. Mr. Kania's extraordinary skill in carving is best seen in these barge-boards.

The nature of the restoration of the front wall is indicated by figs. 3 and 5. The greatest difficulty was presented by the central carved plank, in which the sides had been adzed down and the central part of the lintel chopped out. The sides presented no difficulty, but the lintel remains the most difficult and the least successful part of the whole restoration. The two outward-facing *manaia* and the central human figure were certain, but the disposition of limbs and of other figures in the intervening spaces was purely conjectural. None of the photographs from other museums were of use, and the final restoration was based on an ancient dwelling-house lintel in the Hocken collection.

FIG. 5.

Fig. 4 shows the *pataka* as set up in the University Museum. In order that the front wall might be properly lighted for purposes of the photograph, the roof was left off, and this gives the *pataka* a somewhat flat appearance.

The carving of the original storehouse was executed with stone tools, in the best style of the district of its origin, and with no trace of foreign influence. The *pataka* must have been much finer than any now in existence. The present *paepae* is interesting, but it was executed with steel tools by a carver who had learnt his trade with metal tools and who was influenced by missionary ideas. It probably comes from a different district, as is suggested by the very different rendering of the *manaia* figures.

The restoration is believed to be the largest ever undertaken on a Maori house.

THE INDEPENDENT EVOLUTION OF IDEAS.

By JOHANNES C. ANDERSEN.

IN all arts where certain materials are taken and worked into desired shapes the expression of the working mind is limited by the materials employed; and the cruder the materials and the means available for shaping them, the cruder will be the result. The crudity of the result will vary in degree, of course, according to the lesser or greater development of the working mind.

The result is always interesting for its own sake; but for ethnological comparative purposes it is necessary to know the procedure as well as the result—to know the means by which the result was obtained, apart from the materials used. The finished results, the manufactured artifacts, useful or ornamental, may in appearance be exactly the same, yet the means by which they were produced may be quite different. The finished artifacts reveal the ideal of the thought; the methods show how the thoughts worked to attain that ideal.

This idea has been made very clear during the study of Maori and other string-figures. Figures of this kind are produced by peoples in all parts of the world, civilized and uncivilized alike, but especially among the latter, where other means of amusement are comparatively few. It has been found that certain of the Maori figures have counterparts in other parts of the world. It is not yet definitely known how widely spread these similar figures are; the areas scientifically investigated have been few, and the figures recorded are no doubt a very small proportion of those commonly in use. Much good work has been done in the Pacific and a few places in America, notably by Haddon, Rivers, Compton, W. E. Roth, Jenness, and others, and Mrs. Jayne's book is a storehouse for comparative purposes; and it is not surprising that most of the parallels with Maori figures have been found among Pacific figures. The Pacific area has been better worked, and the mentalities of the Maori and other Pacific peoples are more closely akin.

Seeing these similar figures—in appearance many of the final forms are identical—the first thought was that these had resulted at a time when the now scattered peoples were united, or were at least neighbours: that is, that the figures had a common source. Among figures so far collected, some, in their final form, appear common to most peoples; some are found only within certain restricted areas; as if, according to old theory, the figures known in common had been remembered and were a common possession, whilst each people had, since separation, evolved others now peculiar to itself. These latter are usually the more complicated figures. For instance, few figures recorded so far from any locality are as complicated as the Maori *ara pikipiki a Tawhaki* (1), and no figure at all similar has been seen recorded from elsewhere. The best Maori figures are not merely symmetrical geometrical shapes; they are often unsymmetrical, and represent an incident or a series of incidents. One complicated figure represents the volcanic White Island and the *puhi* (steam-cloud) rising from it; various changes in the figure represent the varying appearance of the *puhi* according to the four chief directions of the wind. A localized

name need not necessarily, however, imply origin in that locality, as the myth of Maui and his fishing exploit shows.

The figures that are common are usually the simple ones. Here, again, it may be that this is because collectors have been able more easily to collect these, for it requires some patience, as much on the part of the native as on the part of the collector, to record a complicated figure; or it may be said that this is because the natives themselves remembered these simple figures more easily, carrying the memory with them as they moved from place to place.

Here, however, is where doubt enters; and here is seen the necessity for recording the procedure, and not only the finished figure; for, whilst the finished figure may be known in many widely scattered areas, the method of producing the figure differs, and often differs widely. It is easy to realize, too, that whilst there may be several ways of producing a simple figure, there can be very few ways of producing a complicated one.

For instance, the figure known as "the leashing of Lochiel's dogs" (2) is, according to Mrs. Jayne, known in England, Scotland, and Ireland, in Africa, North America, and was introduced by the French into Algeria; and latterly it has been found to be known to the Maori and to the Samoan. It has a great number of names—"tying dogs' feet," "cock's feet," "duck's feet," "the wooden spoon," and, amongst the Maori, *kaheru* ("the spade"). Whilst the figure is identical in so many scattered areas, however, the methods of producing it are quite different; these are given in (2), and experiment has shown that there are many more methods possible.

It is not a particularly attractive-looking figure; its charm is no doubt in the catching of the loops in the leashes when the loose strings are pulled taut. It will be noticed that, according to the method employed, the loops in the final figure are held by different fingers. The European method leaves them on the middle and little fingers; the Samoan on the thumbs and little fingers; the Indian on the wrists and little fingers; the Australian (Queensland) on the thumbs and forefingers; the Maori on the thumbs and middle fingers. Moreover, the Maori form has a continuation, "the trapping of Tama te Kapua," and in the Indian figure the leashing is not really a figure at all, but merely a step towards the final figure, "the two tents." The Australian figure is the same in appearance, but unfortunately no procedure has been recorded; only the drawing of the final figure is recorded; it is named "the four-pronged spear" (6).

Again, the figure *komore* (3) is the same as "the kingfish" from the Caroline Islands, but is produced differently; and the difference is in the production of opening A, and is vital; the right palmar string must be picked up first. Unless one is familiar with the figures it is not realizable how difficult it is to vary the habit of picking up the left palmar string first. In most of the figures it does not matter which is picked first, but in one or two the order is vital. A difference of this kind is, therefore, a strong indication of independence of origin. *Komore* is also the same as an unnamed figure from New Caledonia. In some parts of New Zealand only the simple figure is known; in other parts there is a beautiful continuation (4), quite different from the kingfish "catch" continuation of the Caroline Islands, and both are utterly different from the most ingenious and attractive New Caledonian continuation (4). This continuation is not possible in the Maori figure, owing to the way in which the figure is extended.

Other parallels have been noted, in particular an ingenious one between Maori and African figures, which will appear in later records.

These figures seem to show quite clearly that the differences in method are not due to faulty memory, but to thought and imagination running in similar channels under similar influences. For some reason, as yet obscurely comprehended, certain shapes please, others do not please, and of the latter, no doubt, scores have been rejected where one of the former has been retained.

In some instances the names may differ in figures of similar design, whilst the significance of the figures is the same. This seems to be especially so in those that have been invested with a sexual significance, such as "the butterfly" of the Loyalty Islands (5) and *wahine* of the Maori; but even here the name-giving shows the thought and imagination running in similar channels.

This independent evolution of ideas does not confine itself to the production of tangible things such as string-figures, woven and plaited artifacts, pottery, and the like. It is far from improbable that primitive man, and cultured man too, in the presence of the great nature-forces around him, should evolve similar ideas regarding them, expressing those ideas in a way that has given rise to theories of a common origin for those ideas. It is true they have a common origin—the general mind of man; but the ideas may have taken shape independently in different places and at different times, tapping sources, it may be, that have no constricted habitation and abode. That is, like ideas may exist in the minds of man, not dependent upon physical contact or intercommunication for their origin.

Thus in Scandinavian mythology certain of the adventures of Thor are strikingly similar to those of Maui in the Maori; there are like similarities in Greek and Maori mythology in deeds of Apollo and Maui. Solar myths may easily be of independent origin; and whilst Maori and Hindu may at one time have been in contact—as it is also said Maori and Egyptian have been—their similarity of expression of ideas regarding powers of nature need infer no common origin for the different peoples. They had like minds, and is it strange if in like environment they should give expression to like thoughts?

Even in language the parallel may be urged. Peoples separated by wide tracts of land or sea—who have apparently been so separated and isolated for hundreds of years, or thousands—may have identical words for the same object whilst their languages as a whole are entirely different; yet they need not have acquired the word from any other common source than the common human mind.

The very first articulate sounds are automatic, mechanical. The vowel *ah* seems to be the first sound uttered by the newly-born child; and when the sound is attended with a momentary closure of the lips the sound *ma* is produced if the nasal passage is open, the sound *pa* if the nasal passage is closed. By natural iteration these sounds become *ma ma* and *pa pa;* and, hearing those sounds, the fond young mother, knowing nothing and caring less about their mechanical production, discerns in her child a precocious intelligence. Once the child, like the lamb, discovers that these sounds, especially the sound *ma,* produce an agreeable result, their use through association is fixed. *Ta ta, ba ba,* and the like follow. These earliest articulate sounds are all due to momentary mechanical stoppages of a half-involuntary vowel-sound. Language soon leaves these primitive

channels, of course, but they are an indication of how automatic, how mechanical, it is at its source. *Papa* is the word for father in Maori as in English ; *Ra* for the sun in Maori as in Egyptian ; *whea* and *where* convey the same idea in Maori and English.

Is it pushing the parallel too far to suggest similar action in physical nature ? Given similar materials, similar conditions, similar powers of conversion, is it not natural for similar forms to evolve ? It is so in the mineral world : why not in the more complicated vegetable and animal world ? This is a question whose answer has been attempted by thousands, and will be attempted by still unsatisfied thousands.

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THE GEOLOGICAL PROBLEM OF THE PACIFIC AREA.

A Lecture by Professor W. N. BENSON, before the Otago University Club.

ON his return from the Pan-Pacific Science Congress in Australia, Professor W. N. Benson delivered at the Otago University Club an address on the geological work done at the meeting. He stated that, though the geologists considered over a hundred papers, a general theme ran through most of them, so that it was possible to group them into a single summary, though they touched on many phases of geological science. The great problem at the back of all discussions was the geographical unity of the Pacific lands not only in the present, but also in the past. This unity is expressed in many ways : in the altitude of the earth-folds in the marginal lands as regards the ocean on the one hand and the continents on the other ; the more or less definite contemporaneity of the successive epochs of deposition of marine sediments or periods of crust-folding in the different countries ; in the similarity of age, composition, and mode of occurrence of the igneous rocks in the marginal lands on the one hand and the oceanic islands on the other ; in the special features of the existing volcanoes, strung as they are along the border of the Pacific basin from the Aleutian Islands to Japan, the Philippines, New Guinea, New Hebrides, and New Zealand ; in the similarities and differences in the flora and fauna, marine or terrestrial, about the Pacific basin in present and past time—as indication of the former continuity or isolation of the various marginal lands ; in the similarity of the coastal land forms in the circumpacific region, which give evidence of a like geographical history throughout within comparatively recent times, showing uplift or depression of the coasts, with important effects on the

distribution of coral reefs: these and many other features point to the general unity of the whole oceanic area. The Pacific Ocean is the grandest geographical feature in the world, and the solution of the problems involved in tracing its ancestry would take us far back into the study of the genesis of the world itself. This was the great task the geologists at the Congress set themselves to attack. Needless to say, it was not solved; the work of generations of students will be required for its solution. But congresses such as these do what no single student can in the way of bringing together and sifting through facts gained in many lands, seeing their possible correlation, picking out promising lines for further research, and giving the individual workers the stimulus of friendly association with those attacking the same problems in other lands.

It was customary at the Congress to devote a single day or half-day to each topic, such as the various features mentioned above. After a brief introductory exposition of the problem by some outstanding authority there was a rapid succession of about a dozen terse statements from the delegates of the information bearing on the problem in hand in the particular country represented by each, after which such time as remained was devoted to a summing-up and discussion of the facts that had been presented. The last, however, would not lead very far at a single session of the Congress, for the mind could not assimilate and consider adequately in the short time available the vast amount of new material that had been given to it in such highly concentrated form. The future Congresses, however, will build on the records of the former meetings, and follow up the many pregnant suggestions or tentative generalizations that have been thrown out from time to time.

The first day was devoted to a series of statements concerning the younger formations all around the Pacific and the West Indies. In each land where we see marine beds and fresh-water formations alternating we recognize the record of the sea's advance over the margins of continents, the formation of sediment in this drowned strip, the backward movement of the sea, laying bare those same sediments, which become channelled by rivers, or covered with gravel or lacustrine deposits in which may be entombed the plants and animals that inhabited the land. Thus by the double standard of marine and fresh-water or land organisms we seek for means of dating as accurately as possible the fluctuations of the sea-level. Is it the case that the floodings of the sea on to the land are simultaneous around the Pacific, or is a retreat of the sea in one area accompanied by a compensating advance on to the land in another? Or, again, is it possible that the two relations may hold, sometimes one and sometimes the other? The answers to these questions are of great importance in the understanding of the mechanism of earth-movement. So it is necessary we should have a means of finding as exactly as may be the relative age of formations, and for this the remains of the rapidly evolving land-mammals form a much more delicate test of the age of the sediment that contains them than do those of the slowly changed and less specialized marine shells or land plants. To obtain a fullest record of the evolution of the land-mammals we must go away from the coastal region, where the terrestrial record is interrupted by incursions of the marine, to the heart of the continents from which the sea has been absent since the dawn of mammalian life.

Biologists have long looked to the highlands of central Asia as the place where great evolution of mammals took place, the ancestral home of races that have migrated far and wide. To test the truth of this, the American

Museum of Natural History sent an expedition into the Gobi Desert. Financed, organized, and staffed with American thoroughness, it covered over three thousand miles of desert previously unexplored by scientists, and returned with a great wealth of vertebrate remains in which the succession may be traced from the period when the giant reptiles flourished through various stages of mammalian evolution up to the present, though as yet only a preliminary study of the collections has been possible. The story of this scientific adventure was put before the Congress by Dr. Hovey, of the American Museum. From the bordering lands of this central continental region, Saghalien, Japan, Java, Burma, and the Himalayas came new details of the alternation of marine and fresh-water beds (with their mammalian remains) which told of the oscillations of the coast-line (or of the sea-level), and the last paper dealt especially with the crust-movements leading up to the building of the Himalayas, which occurred, geologically speaking, quite a short time ago. Other information on the same lines came from Victoria, and from Central America, and thus gradually our knowledge of the relative age of the earth-movements is increased.

Now, why this desire so carefully to date crust-movements about the Pacific? This: If it can be shown that the movements in one region have been repeatedly part and parcel of a system of simultaneous movement all round the Pacific, there is evidently a genetic connection between them. They must arise from a common cause, a force developing within the ocean basin itself leading to a crumpling of the flexible ring of the earth's crust which surrounds it and separates it from the more rigid continental masses. To explain this we get back to something fundamentally connected with the nature and origin of the world itself. What it is we do not yet know precisely, but an idea was thrown out by Professor Cotton, of Sydney, that will surely receive more attention in the future. We take for consideration the swinging of a clock-pendulum, at first sight quite unconnected with anything geological. The time of the swing of a pendulum depends on its length and the pull of the earth-gravity. If we take a clock to a portion of the earth's crust which is underlain by a vast mass of heavy rock the strength of gravity would be greater than normal, and the pendulum would beat more quickly. On the other hand, if under the surface of the earth was a large mass of abnormally light rock, gravity would be less than normal, and the pendulum beat more slowly. By this means it has been ascertained that the Pacific Ocean is underlain by notably heavier rock than underlies the surrounding continents, and its continued existence results from its constant sagging down, while the continents are buoyed up by the plastic yielding of the thus unevenly loaded interior portions of the earth. But, further, we know the earth is not still, but rotates. Now, a heterogeneous body that rotates, remaining in equilibrum, must have its heavier and lighter parts adjusted to certain positions or distances from the axis, which depend on the rate of rotation. But this rate is not constant for the earth. The daily course of the tides under the attraction of the moon acts as a vast brake which slows down the rotation. Gradually, then, the adjustment of the various dense masses within the earth becomes more and more out of equilibrium, and vast strains are set up until the earth's rigidity is overcome and readjustment of its several portions occurs, with consequent warping and wrinkling of its surface. The periodic readjustments of the great heavy masses beneath the Pacific are, on this hypothesis, the cause of the successive warpings and dislocation of the earth's surface about its margin. Such was the new suggestion put before the Congress.

Besides this explanation of folding on the margin of the Pacific, there are two other hypotheses of the origin of crust-movement as a result of its unequal weighting The first was conceived in the study of the Himalayan survey, and the Congress was fortunate in having to expound it Sir Gerald Lennox-Conyngham, recently head of the Geodetic Survey of India. Think of a carpenter's plumb-line. It hangs vertically downward because its bob is drawn by the earth's gravity towards its centre. Now, if the earth were homogeneous, a plumb-line hanging at the foot of the Himalayas would not hang vertically downwards, because in addition to the attraction towards the earth's centre there would be a sideways pull exerted by the mountains on the one side, not counterbalanced by any attraction in the other direction, where only the broad plains of the Ganges Valley stretch away for very many miles. Actually, however, the reverse is the case. Instead of being pulled towards the mountains, the plumb-bob is pulled away from them, and the only reasonable explanation is that the crust of the earth beneath the low land is dense and acts more strongly on the plumb-bob than does the lighter though more bulky mass of rocks that makes up the Himalayas and their foundation. Thus again we have an equipoise of heavy lowland and lighter highland, just as we had of heavy ocean-floor and lighter continent. A new factor now appears. The myriad torrents from the great range carry yearly a vast mass of soil, gravel, and huge boulders down from the mountains, and deposit them on the foothills and the plain. The mountains thus gradually lose their weight and a load is put on the lowlands. At first sight we might say that, as the equilibrium has been disturbed by the removal of load, the loaded plains must sink a little deeper, and the unloaded mountains be thrust up a little higher to restore the balance as soon as the strain set up is sufficient to overcome the earth's rigidity, and thus the mountains are perpetually renewed. So, indeed, ran the reasoning in the earlier stages of the hypothesis. But would we not be mistaking a very superficial effect for the true cause, which may lie much deeper ? The notification recently announced suggests this is the case. Any portion of the earth's crust is made up of numerous elements, grouped into various compounds called minerals. It is often possible to group precisely the same amount of the different elements into diverse combinations or minerals, one grouping favoured by one set of conditions, another by another. Now, just as a regiment would occupy a smaller or larger parade-ground according to the way its units were grouped, so, while remaining of precisely the same total composition chemically, rocks may be so changed as regards the grouping of their minerals that under one set of conditions they may occupy comparatively little space or be very dense, while under other conditions they may be more bulky and consequently less dense. If, then, conditions were to change within the earth, it is conceivable that the rocks of the heavy crust under the present lowlands might recrystallize into their lighter, more bulky form, and the rocks beneath the mountains into their denser, less bulky form. If this were to happen, the subcrustal swelling in one region and the contraction in the other would result in the elevation of the earth's surface on the one hand, its depression on the other. In this hypothesis, the continued growth of the Himalayas by the expansion of the rocks below, and the continued depression of the Gangetic plain by the contraction of the rocks below, has made possible the continuous washing-down of the gravel, &c., from the mountains to the plains, which is thus a minor effect and not a prime

cause of the mountain-growth. This conception of mountain-growth may come as a modifying factor, not as an alternative to that suggested by Professor Cotton.

Related to these great movements are the features of igneous activity, both deep-seated and superficial. Rocks within the earth are extremely hot, above their normal melting-points, but kept solid by the huge pressure to which they are subjected; but when during earth-folding that pressure is relieved some portion of the crust may become molten, and so free to be squeezed hither and thither through the crust until it cools and solidifies, either within the crust as great masses of plutonic rock, granite, and the like, or, after having been ejected through vents or fissures, it is erupted from the surface and flows out over the land or sea-bottom, or piles up great cones of volcanic ash, the result of explosive ejection. Thus around the mobile margin of the Pacific we find the most marked zone of volcanic activity now in existence, while rents and fissures of rather different origin cause the volcanoes of the islands dotted about within the Pacific area. These, too, received discussion at the Congress, and great interest was displayed in the splendid work of the volcanological survey of the East Indies, and that being carried on near Honolulu, in the crater of Kilauea. The need for similar study of our New Zealand volcanic region becomes very evident.

A very special interest attaches to those portions of molten rocks which consolidated within the earth and were not connected with volcanic outbursts. A volcano erupts explosively because the molten rock it ejects contains a large amount of gas, water-vapour, &c., which must expand when able to do so. No such free expansion is possible for the vapours and fluids given off from the molten rocks which solidify within the earth's crust, but they carry in solution the metals that were distributed through the molten rock, and, penetrating into the fissures in the earth's crust, they deposit the valuable ores. Hence the origin and age of the metalliferous veins around the Pacific are intimately connected with the structure and origin of the Pacific basin itself and that of its surrounding land-masses. A brilliant suggestion concerning this problem was put forward by Mr. Andrews (Government Geologist of New South Wales, author of the recent magnificent volume on the Broken Hill region), and was one of those sweeping generalizations which, by reason of the very exceptions that spring to the mind, call for immediate inquiry and discussion.

There is, however, yet another effect of the forces of earth-folding, the importance of which has been recently manifest. The growing strains in the crust, as various portions get increasingly out of adjustment, result in little fractures and slippings of the rock-masses over one another; such are expressed on the surface by destructive earthquakes. Now, the new advances in the study of these are twofold. The first put before the Congress by the veteran Japanese authority, Professor Omori, concerned itself with the study of the minor tremors and tilting of the earth's crust, by which the accumulation of stresses could be detected, and the prediction of major earthquakes and volcanic eruptions could be made with some confidence. The great utility of these studies in the saving of human life was shown by one dramatic example—the removal by Government authority (warned of an approaching eruption) of thirty thousand people from one of the Japanese islands three days before the volcanic outburst destroyed nearly every building on it. The second discovery is that every such shock sets up vibrations radiating in all

directions through the earth or along its surface, and differing in some degree in speed and nature according to the materials traversed. These vibrations may pass under oceans or continents, or even right through the centre of the globe, and are recorded by delicate instruments termed seismographs, which may be situated thousands of miles from the site of the earthquake itself. These records, then, afford indirect means of ascertaining the nature of the interior of the earth, and its variation or heterogeneity, and they lend support to the conclusion that there is no general molten interior of the earth, which, except for local and temporarily molten masses, is solid throughout; and, further, that the portions of the crust beneath the oceans are more dense than those beneath the continents, just as the swinging of the pendulum had indicated. Here too, the Congress was favoured by the presence of distinguished authorities from Japan, the Philippines, Java, and Australia, who expounded before it their researches in this, the newest of the earth sciences.

Essentially related to all these problems, though at first sight perhaps totally distinct, were two other matters in which research has been very active, and the data concerning which were discussed before the Congress. These were the problems of the last great Ice Age, and that of the origin of coral reefs. In all lands around the Pacific, even in New Guinea, where mountains rise to sufficient height, there is evidence that in the not-very-distant past extensive glaciers existed, filling the valleys in the high mountains or even debouching on to the lowlands (such, for example, as the Clinton Valley glacier, which broadened out into an ice-sheet filling the Te Anau basin). Was this refrigeration brought about by an upthrusting of the land-masses into the higher, cooler layers of the atmosphere, thereby deflecting the normal circulation of planetary winds? Such elevation would necessarily be accompanied by the increase of land areas, and the lifting above sea-level of isthmuses connecting formerly separated land-masses and permitting the intermigration of plants and animals. Or, on the other hand, was the cooling brought about by some fluctuation in the supply of heat received by the earth from the sun, which, like other stars, may be variable? The latter is the view to which American and Australian thought seems to be tending, though up to the present the British and New Zealand geologists have inclined more to the former hypothesis. Again, was the oncoming and retreat of the ice due to a single climatic fluctuation, or were there here, as in the Northern Hemisphere, a succession of several closely following periods of cold separated by warmer spells? The evidence for this would be found in the study of land-forms—partly in the distinction between the broad valleys smoothed by the slow-moving glaciers, and the gorges notched in them by the dashing torrents during the intervening periods of warmth, and partly in the alternation of layers of boulder-clay and gravels laid down by the successive glaciers and the streams which drain from them.

Again, the withdrawal of water from the sea, when in the form of ice-sheets it was accumulated on the land, must have meant a lowering of the sea-level even in tropical regions, with a great effect, therefore, on all the geographical and biological features of the seashore. Darwin, it will be recalled, explained the origin of coral reefs by the gradual upbuilding of the coral about a sinking coast, and thought the abundance of the reefs in the Pacific was due to a general subsidence of the ocean-floor. But may not this apparent subsidence be really due to the rise in sea-level as the great glaciers melted and gave back their imprisoned water? What

significance shall we put, for example, on the reef-dotted, shallow South China Sea? The floor of this is evidently an old lowland plain, which once connected the Malay Peninsula, Sumatra, and Borneo, and has now been drowned to just the depth (30–40 fathoms) that theory would lead us to expect would be equal to the rising of the sea-level as the ice melted. Or, again, what significance shall we attach to those Pacific islands that show signs of instability—not merely of subsidence, but of some elevation, and tilting? Perhaps, after all, the problem of the origin of coral reefs is not so completely solved as may have been thought, and other factors than those considered by Darwin may bear importantly on the problem. It was, however, satisfactory to find a full accord with the correctness of Darwin's explanation in many cases, and notably that of the Funafuti atoll, where some twenty-five years ago Professor Sir Edgeworth David put down a bore for 1,114 ft., finding all the way down shallow-water types of coral standing upright in the position of growth.

Such were some of the questions discussed at the Pan-Pacific Congress. Space would fail us to describe the other matters dealt with: the present and possible oilfields and the other mineral resources, the detailed work of the official Geological Surveys in the lands around the Pacific, and other matters of more academic interest. Suffice it to say that interest was quickened and advances recorded in nearly every branch of geological science, and the work of teacher and investigator alike throughout the countries represented must be increased in value as a result of this most important Congress.

THE MECHANICS OF NATURAL FLIGHT.

By H. HARDCASTLE.

FEW, if any, natural phenomena in the daily view of man are less commonly understood than the flight of birds and insects. Indeed, the bewilderment placed on record in Proverbs is shared in a modified form by some of the most ardent students of the subject, and there are several so far unexplained and possibly unexplainable things about "the way of an eagle in the air." No attempt can be made here to deal with more than the broader principles of natural flight; but this can be stated as a foundation the realization of which will tend to check unprofitable diversions of thought: flight is a purely physical phenomenon, explainable in all respects in terms of well-known mechanical actions and reactions. It has been well remarked by F. W. Headley, in *The Structure and Life of Birds*, that "however tempting the theory may be that a Senior Wrangler has one system of mathematics and a pelican a totally different one, we must not be beguiled by it."

So far as flight presents unsolved questions, the student's chief difficulty is that, having limited vision and not being himself a bird, he cannot ascertain all the physical data that are involved. The really puzzling phenomena of flight have, in fact, been practically reduced to those connected with the finer details of control. It is no longer necessary even for the unscientific to assume the existence of special forms of energy of which

no evidence is available save in the explanations that call forth the assumptions.

Flight, as here discussed, is in all cases due to the reaction of the air (owing to its slight but sufficient inertia) against the surfaces of the special organs which we call wings; and those reactions are due to the rapidity of the motion of the wings through the air and their angular attitude to the direction of their motion.

Dr. J. Bell Pettigrew, whose views have acquired very wide publicity through his authorship of the article on "Natural Flight" in the *Encyclopedia Britannica*, attached enormous importance to the "twist" which he observed in natural wings, and indeed in the bones of animals; and also to the "figure-of-eight" path described by wing-tips. He was led thereby to condemn attempts at artificial flight with wings of rigid form. It is a sufficient answer to his doctrine that artificial flight is achieved with rigid wings, and that, while flexible wings may yet find a use, twisted wings have not survived the many experiments made with them. No virtue resides in the twist of the wing, nor in the doubly curved path of the wing-tip. These are the results, not the causes, of the forces which make flight possible.

It is a point of no small interest that inventors who aimed at human flight achieved no great success while they riveted their attention upon the birds; they neither found the bird's secret nor made good flying-machines. But, departing radically in the structural sense from bird-forms, they flew fast and far; and our now common knowledge of the art of flying by machinery has wonderfully simplified the understanding of natural flight. It has made it possible, for example, to appreciate the minor importance of the act of flapping as an essential part of flight—a point which escaped earlier investigators in spite of the fact that they could see flight accomplished without it. The mystery of flight does not lie in the performance of the flappers; their secrets can all be solved easily enough; it is the art of the gliders and soarers which presents the greatest difficulties to the observer and the theorist. Probably the greatest contribution to our still limited knowledge of the processes of flight has been made by F. W. Lanchester, who published a large work in which the whole subject is exhaustively treated and the fundamental mathematical arguments are clearly set out. This mathematical investigation preceded all but the first crude flying achievements of man; and it is noteworthy that most of his mathematical conclusions were verified by experiments with small models. He devotes some attention to natural flight, but the work is chiefly concerned with an inquiry into principles for practical use in flying-machines.

Bird-flight is of four kinds: flapping flight; hovering; gliding; and soaring. With the first all are familiar. Hovering is uncommon, and is the typical flight of the humming-birds and of insects. Gliding and soaring are not clearly separable. A bird "glides" when it stops flapping and descends at an angle, as the pigeon or gull does prior to landing. This form of flight is the analogue of "coasting" downhill on a bicycle. To soar is to fly for an indeterminate time without any expenditure of bodily energy; and this feat is accomplished in various ways. There is such a marked difference between the performances of sea-birds at low levels and those of birds of prey at high levels that one is tempted to call the low-level art "gliding"; but it is better perhaps to restrict the term to mere descent. The distinction between gliding and soaring is that in the one case the velocity of flight is

due solely to gravitational force and the flight ends when that force is exhausted by loss of height; in the other, while the velocity is maintained by the same means, the necessary elevation is maintained by the use of energy obtained from the air. Soaring birds use flapping flight; but soaring is a special art, developed by the larger birds.

The writer proposes to deal in this paper with flapping flight. A subsequent paper will discuss the power-expenditure in this form of flight, in conjunction with some consideration of gliding, which supplies the key to the question of power; and soaring will be separately dealt with.

As the flapping of the wing is the most conspicuous feature of bird-flight, many of the early investigators regarded it as of fundamental importance, and gave it the closest attention. By combining faulty observation with defective arguments, they arrived at diverse conclusions. Thus arose a lively discussion as to whether the bird struck forward or backward on the down-stroke, this being a most important point with those who believed that flight was a rowing process. A reminder of this idea remains in the term "remiges" (*i.e.*, rowers) applied to the great feathers which form the outer end of the wing. Determined to prove that flight was due to a rowing action, several theorists held that the stroke was backwards, necessarily implying that the appearance of forward motion was an illusion. It was evident to others, however, that the appearance was truthful, and that in fact the obliquity of motion was due not to muscular action but to the pressure of the air. The debate received its death-blow from the experiments of E. J. Marey, of the College of France, who harnesed pigeons, buzzards, and ducks with ingeniously made recording-apparatus and secured graphs of the greatest interest. These experiments were published in English in 1874.

But Marey frankly admitted that his experiments merely confirmed the theory set out two hundred years before by the Italian physiologist Borelli (*De Motu Animalium*, 1680). Borelli, in one of several statements of his theory, said: "If the air under the wings be struck by the flexible portions of the wings with a motion perpendicular to the horizon, the . . . flexible portions of the wings will yield in an upward direction and form a wedge, the point of which is directed towards the tail. Whether, therefore, the air strikes the wings from below, or the wings strike the air from above, the result is the same—the posterior or flexible margins of the wings yeld in an upward direction, and in so doing urge the bird in a forward direction."

The long and somewhat acrimonious discussion on the actual motion of the bird's wing which followed is no longer of scientific interest when it is realized that flapping is purely a propulsive and not a sustaining action. The latter was, of course, the original idea; it naturally seemed that the simplest way for a bird to keep itself up was to beat down upon the air. This motion needed a corollary—that in some way the wing on the up-stroke "evaded" the air in preparation for a fresh grip on the next stroke—and much ingenuity was used to get over this difficulty. One of the suggested explanations—it will not bear a moment's examination, though many people still cherish it—was that the feathers separate on the up-stroke and let the air through.

Two simple points will show the fallacy of the air-treading explanation. The amount of energy required to sustain the weight of a bird by this means alone is far beyond what the muscular system of any bird can

supply. Yet it is obvious that flight is not an exhausting process; and it is easy to observe cases in which the margin between the expenditure of muscular energy and no such expenditure is very small. Again, the amount of force required to move wings through the air with the frequency and velocity actually observed is a mere fraction of the power required for sustentation by direct pressure. A bird weighing 8 lb., in order to sustain itself solely by "treading the air," would have to expend half a horse-power of energy, which is obviously impossible. Borelli was, in fact, exactly right in his explanation, though his statement suffers from lack of clarity. The wing of the bird consists of a structure which may be analysed into a more or less rigid beam supporting a flexible and elastic flap. Motion of this structure in a direction perpendicular to its surface results in the bending of the flap, so that on the down-stroke its under-surface looks backwards, and on the up-stroke the upper surface does so. In each case the resulting pressure can be resolved into two components—one vertical, opposing the flapping motion, and the other acting towards the head of the bird (because the rigid portion of the wing is in the leading edge). Thus, neglecting for the moment the whole question of supporting the weight of the bird, flapping results in a propulsive force on the up-stroke as well as the down-stroke, provided that the flexibility of the wing is sufficient to enable the surfaces to "look backwards" during both strokes.

But the object of the propulsive effort is to secure sustentation. This is obtained solely by the fact that the wing is an aerofoil, precisely similar in function to the fixed wing of an aeroplane or the surface of a kite. Its operation depends upon the fact that its under-surface looks forward, so that, as the bird advances, the wing is subjected to a vertical (upward) pressure which is equal to the weight of the bird.

How can the forward-looking surface required for sustentation and the backward-looking surface required for propulsion be provided at the same time? Only by a subdivision of duty. This is provided for by the nature of the wing's motion. Moving with a hinge-like action at the shoulder-joint, the flapping wing sweeps through the air with a high velocity at its tip and with a low velocity near the body. The propulsive effort belongs to the swiftly-moving outer end; the supporting work falls upon the inner, slowly-moving part of the wing. There is no sharp line of division between the two areas; and, indeed, the neutral line is in different positions at different parts of the wing-stroke. In its shape the wing reflects the two purposes. Great flexibility and elasticity, and often a reduced expanse, is shown by the outer half of the wing, composed of the strong and elastic remiges. The rest of the wing, between the carpal (wrist) joint and the body, is progressively less flexible, and is composed chiefly of a membranous expanse thickly clothed with feathers. This portion of the wing is, moreover, markedly concave beneath; and this is not a mere result of its resting against the rounded body of the bird, but is a special adaptation to flight. A concave or "cambered" aerofoil is far more efficient as a weight-carrier than a flat one. The camber which is so marked a feature of the inner end of the wing is much reduced ("washed out," in aviation parlance) as the tip is approached. This feature is intimately related to the propulsive function of the outer portion of the wing, and in soaring birds appears to be of advantage in securing stability.

The muscular system which operates the wings is of great interest. Anatomists find that, while the whole group of pectoral muscles which

move the wings represent on the average the large proportion of a fifth of the bird's weight, the elevator-muscle is quite inconsiderable compared with the depressor. It is further stated that the two muscles are of different character, the fibres of the depressor being of the type which can work for long periods, while the elevator fibres are of a type associated with intense but brief effort. When a bird starts its flight it must raise its wings as well as lower them. But once it is under way it needs only to depress them. Its impetus carries it forward between the down-strokes; its wings, inclined with the leading edge slightly raised, are pushed upwards by the air-pressure beneath them. The elevator-muscle thus does little or no work, except in the emergencies of starting, stopping, and sudden manœuvring. The wing is thus indirectly raised by the depressor-muscle. It will be evident, too, that the force which pushes the passive wing upwards is acting at the same time to sustain the weight of the bird. The continuity of support is clearly shown by the slightness of vertical oscillations of a bird's path. The common gull's wing makes about 140 strokes per minute. If no support existed during the up-stroke, the centre of gravity of the bird would fall approximately 6 in. during that stroke. Actually the body of the bird does fall slightly; but at the same time the wings have gone up; the drop is chiefly due to reaction. The motion of the centre of gravity is so slight as to be practically imperceptible. Still more is thus shown the fact that there is no general downward pressure of air upon the upper surface of the wing, for that would emphasize the drop due to the force of gravity.

The force which lifts the wing and at the same time sustains the bird has its centre of pressure closer to the body of the bird than the middle of the wing's length, and the outer portions of the wing are swept upwards so fast that they, though not the wing as a whole, may and probably do carry a downward pressure. The result is that the propelling organs, the remiges, again come into play and continue their backward force on this stroke as well.

It follows, from the actions described, that the wing will not describe its motion in a plane perpendicular to the direction of the bird's flight, because the wing is not rigid in the fore-and-aft direction. During the down-stroke the pressure of the air from which the propulsion of the bird is derived drives the wing forward, so that its motion is inclined to the perpendicular. As its velocity is greatest at the middle of the stroke, and the propulsive effort is then also greatest, the motion is curved, convexity forward. On the up-stroke the air-pressure which lifts the wing comes from ahead and drives the wing back, at first nearly horizontally, and then in a curve to the top of its stroke. The fore-and-aft component of this elliptical motion can be clearly seen by watching a gull flying directly overhead. It is an interesting and rather impressive sight.

Undoubtedly the most interesting question connected with flapping flight is the amount of energy required to sustain it. The determination of this quantity is probably impossible; but it is certainly not large, even in birds which, using their wings very rapidly, appear most energetic. It takes very little effort to flap a surface like a gull's wing 140 times a minute in stationary air; but actually the amount of work involved when the wing is travelling as in flight is far less. The effort of flight is indeed as inconsiderable as that of walking. Its actual quality is measured not in terms of the weight of the bird, but by the resistance offered by the air to its motion at the speed of flight. This is a question which is not

appropriately dealt with at this stage; it belongs to the discussion of soaring and gliding flight.

The following circumstances thus appear in the performance of bird-flight of the ordinary type in which the wings are flapped:—

Motion of the wings (flapping) plays no important part in sustaining the bird's weight; it is almost wholly a propulsive effort.

The bird is sustained almost entirely by the wings acting as aerofoils, just as the wings of an aeroplane do.

The propulsive force is exerted mainly in the down-stroke of the wings, but there is a differential action during the up-stroke which results in the extremities of the wing continuing to drive the bird forward. The energy thus expended is subtracted from the momentum of the moving bird.

The sustaining force, if not constant, is at least continuous: the net air-pressure on the wing as a whole acts upwards,

The essential condition in a flapping wing is that it shall have a skeleton or a pseudo-skeleton in or near its leading edge, and that the rearward expanse of the wing shall be flexible but elastic.

Analysis of the motion of the wing shows that its track, relative to the bird, is elliptical, with the longer axis inclined, backwards above and forward below, from the vertical; but this ellipticity is a mechanical effect and is not an essential or important condition of flight.

FRESH-WATER EELS AND THEIR LIFE-HISTORY.

By GILBERT ARCHEY, M.A., Curator, Auckland Museum.

THE question, "Where do eels breed?" has long waited for an answer. That they do not breed in the rivers in which they spend seemingly the greater part of their lives has been known for long enough, and the alternative answer to our question—that they breed in the sea—has been stated in terms as broad and vague as the wide ocean itself.

I write of the European fresh-water eel, *Anguilla vulgaris*, the final elucidation of whose life-history is one of the triumphs of contemporary science. The honour of the discovery belongs to Dr. Jos. Schmidt, a Danish scientist, who nearly twenty years ago had come upon some significant facts in connection with this subject, and who was therefore especially appointed by the Government of his country to continue his inquiries until he should have reached a solution of the problem.

As long ago as 1856 a small transparent ribbon-like fish was described by Kaup, who named it *Leptocephalus brevirostris*. It was taken on the surface of the sea in the Straits of Messina, and for nearly forty years its relationship to other fishes remained obscure. In 1895, however, two Italian scientists, Grassi and Calandruccio, demonstrated that it was the larval stage of the fresh-water eel which lived in the streams of Mediterranean countries. The obvious inference was that the eels descended

to the depths of the Mediterranean to breed, and that the leptocephalus larvae, after a short existence on the surface, changed into the minute eels, long known as "elvers," which ascended the rivers in the spring. Elver-fishing, it may be noted, has been an extensive industry at the mouths of several European rivers for many years.

The explanation given above was satisfactory enough so far as the Mediterranean eels were concerned, but an equally simple explanation would hardly cover the life-history of the same species of eel in north Europe. For instance, while elvers were known at the mouths of practically all European rivers, including those of the United Kingdom, "leptocephali" were not known in the North Sea, where one would expect to find them.

The discovery in 1904, by Dr. Schmidt, of leptocephali in the Atlantic, west of the Faroes, was the clue which put that scientist on the track of his final discovery, which was not made until after eighteen years of patient calculated research. The Danish Government placed a specially equipped vessel at his disposal, and by 1906 he had shown that the eels, at any rate, of north European rivers were bred in the Atlantic well to the west of Ireland. He than shifted his inquiries to the Mediterranean, and by 1910 had proved that the Mediterranean leptocephali did not hatch there, but came in from the Atlantic through the Straits of Gibraltar. The first suggestion which followed this demonstration was that the eels bred in the deep water lying just outside the great European submarine shelf; but Schmidt argued that the leptocephali found on the surface above the edge of this shelf were too large to have originated there, and that the actual breeding-place must be farther out in the Atlantic.

He then proceeded with a systematic search over the Atlantic, setting the compass of his inquiries in the direction of the reduction in size of the leptocephali. His work was interrupted by the war, but by the end of 1921 he had found the youngest leptocephali, many with parts of the yolk still attached, swarming on the ocean surface in the Sargasso Sea not far to the south of the Bermudas, four thousand miles away from Europe. It is the current of the Gulf Stream which brings the little leptocephali to Europe, for they have only limited powers of swimming; but it is a slow journey for them, as it is not until the spring of their third year that they reach the coasts of Europe, and, changing into "elvers," ascend the streams and rivers. Here they grow to adults and live for a period estimated up to seven years, when they assume a silvery hue, and their eyes become large and protruding, characteristics common among deep-sea forms.

The wonderful breeding migration of these mature eels to the ocean has been traced both through the Baltic and the Mediterranean, but the course and depth of their journey across to the western Atlantic is as yet unknown, and is now engaging Dr. Schmidt's attention.

One interesting result of the elucidation of this remarkable life-history, which requires a quarter of the circumference of the globe for its completion, is that it explains a puzzling feature of the geographical distribution of the eels. While they are found in all the rivers of Europe, they occur in the streams of west Africa only as far south as Rio de Oro, in Senegal. It will be remembered that the current of the Gulf Stream carries the little larvae eastward towards Europe, and a glance at a map of the Atlantic will show that the southerly branch of the Gulf Stream is reflected backward from the coast of Africa opposite the Rio de Oro. Any leptocephali or elvers which have not ascended a river by the

time the current reaches this place will be carried to sea, presumably to perish.

Another interesting fact is that, while the eel which lives in the streams of North America (*Anguilla rostrata*) is a different species from the European form (*A. vulgaris*), its breeding-place was found by Schmidt in the Atlantic, not far south-west of that of the eastern species, the larvae of both kinds being sometimes taken together. What particular sense, therefore, attracts the American leptocephali to the west, and keeps the others fixed on their long journey? Schmidt found that the larvae of *A. rostrata* remain larvae for only one season, instead of three. They, therefore, change into elvers while still near the coasts of America, and consequently seek at once the fresh water entering the Atlantic on their left.

The story of this wonderful breeding migration of four thousand miles of the European fresh-water eel suggests again the question with which we commenced this article. Where do New Zealand fresh-water eels breed? Do the eels of our rivers have similar larval stages, and do they perform a great migration and drift as the European eel does? We have not much information as yet on which to base speculations, but what little we know is as follows:—

There are two species of fresh-water eel in New Zealand, separated by not very great but apparently constant differences. The first, *Anguilla aucklandii*, which may be called the New Zealand fresh-water eel, is confined, so far as I can discover, to New Zealand and the Auckland Islands. The other, *A. australis*, has been taken from Timor, eastern Australia, South Australia, Tasmania, New Zealand, and the Auckland and Chatham Islands. These distributions are curious, and suggest that the specific characters and distribution require re-examination; moreover, we have much yet to learn of the distribution in New Zealand of these two species.

As to their probable life-history, we do know that leptocephali are occasionally taken off our coasts, but we do not know of which eel they are the larvae. In the Canterbury Museum there are elvers of *A. australis* which were caught at the mouth of the River Styx in September, 1915, by Messrs. T. Cheston and H. Unwin.

The absence of eels from above large waterfalls also points to a marine spawning migration. The actual spawning-place, however, can only be guessed. If we accept the present species and their distribution as correct, and if we further suppose that the breeding-place (of *A. australis*, at any rate) is some central spot in the tropical part of the Pacific, we have to select a spot from which currents flow to all those places in which *A. australis* lives. The maps I have consulted do not show such a spot, unless it be the east central Pacific, whence currents go to all those places except South Australia and Tasmania. Such a spot may, however, not be necessary, for Schmidt found the earliest leptocephali of several species of marine eels in the Mediterranean, and our fresh-water eels may possibly breed not far from shore. There, however, we must leave the problem for the present, for want of information, which, without a properly organized expedition, may take years to collect. The whole question has many interesting aspects, and I will conclude by quoting one which was put to me recently. How do mature eels escape seaward from the lagoon-mouths of many of our rivers, and how do the elvers get past the banks of sand and shingle to ascend these rivers when they have completed their supposed leptocephalus migration or drift?

THE ROLE OF THE TREE-FERN IN THE NEW ZEALAND BUSH.*

By AIRINI POPE, M.Sc.

PART I.

ARBORESCENT ferns are characteristic of rain forest generally, and, although they are most numerous within the tropics, yet South Australia, New Zealand, and the southern Pacific islands all possess their own representatives. In New Zealand, indeed, it is to the tree-ferns that the bush owes its most striking characteristic.

In all early descriptions of the forest of New Zealand, the writer is impressed by its sombre colouring and lack of definite character. Hochstetter says, "The verdure of the ever-verdant bush is not a rich sap-green, but a dim brown-green"; and later, "very few trees grow gregariously . . . more than a dozen varieties may be found on the same acre. The forests, therefore, have no particular physiognomical character"; and it is almost with relief that he notes the "magnificent tree-ferns" rearing their beautiful crowns above the lower trees. Similarly, Hooker in his *Flora Novae-Zealandiae* remarks on the tree-ferns as being practically the only plants that would strike a superficial observer of our forest. And indeed they do not belie this first impression, but play an important as well as a striking part in the life of the forest.

Tree-ferns proper are practically all members of the family Cyatheaceae, which includes seven genera—*Cyathea*, *Alsophila*, *Hemitelia*, *Dicksonia*, *Thyrsopteris*, *Cibotium*, and *Balantium*—of which only the first four, comprising eleven species, are represented in New Zealand. In the Wellington district, where the observations embodied in this paper have been made, the commonest species are *Cyathea medullaris*, *Cyathea dealbata*, *Dicksonia squarrosa*, and *Hemitelia Smithii*.

GENERAL DESCRIPTION.

The stem is generally unbranched, erect, and columnar; from the apex springs the spreading crown of palm-like fronds. These are sometimes 15–20 ft. long, and broad in proportion; and when we say that a *Cyathea medullaris* will sometimes have as many as thirty-six fronds it will be understood how wonderful a sight it may be. In many cases the rhachides (shafts of the fronds) are gracefully arched, in others almost plane. The young fronds are circinately curved; and it is imagined that the spirals which play such a large part in Maori carving owed their inspiration to the young curled fronds of the tree-ferns.

MORE PARTICULAR DESCRIPTION OF SPECIES CONCERNED.

Cyathea dealbata.

Habitat.—Throughout the North Island, and parts of the South Island, as far south as Akaroa.

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* Presented as a thesis for Honours (M.Sc.) at Victoria University College.

This is the "silver tree-fern" of the settlers. The native name is "ponga." It is cultivated at Kew. *Cyathea dealbata* is the most graceful of New Zealand tree-ferns, being conspicuous for the milk-white under-surface of its leaves. The trunk is sometimes 40 ft. high, the fronds 8–12 ft. long and 2–3 ft. in breadth. It grows in no other part of the world.

FIG. 1.—*Cyathea medullaris* (*a*) and *C. dealbata* (*b*), showing different methods of leaf-fall.

When young, the fronds grow out at an angle of 60° or 70° to the perpendicular, and arch gracefully. As the tree-fern grows older this angle increases, till in the mature form they are practically horizontal. Sometimes, however, when other plants are crowding round, the fronds of even a mature fern will grow up at an angle of 30° to the perpendicular,

thus forming an inverted cone, and placing all the leaves in such a position as to make the best use of the available light.

The dead fronds are generally all retained until the trunk is 4–5 ft. high, and after that they are dropped fairly soon. In some cases the stipital remains will cover a stem from top to bottom; in others half-way down; and sometimes on one side only. Seldom, however, is the stem quite bare. (Fig. 1, *b*.)

Aerial roots are given off for a considerable distance up the stem, forming a wiry fibrous covering. When the fern has attained some size, the base of the stem gradually enlarges by the addition of these roots until it reaches perhaps 18 in. in diameter.

Mr. Edgerley says that the pith is eaten by the Maoris, as is that of *Cyathea medullaris*, but this statement wants confirmation.

FIG. 2.—*Cyathea medullaris* in an exposed situation withstanding severe desiccation from wind and sunlight.

The fronds were used for distinguishing a track through the bush on a dark night, by laying the fronds along tip to stem, under-side up. The white under-surface shows up very clearly.

Cyathea medullaris.

Native name, "mamaku" or "korau."

Habitat.—Throughout the North and South Islands, as far south as Akaroa. It is cultivated at Kew.

This is a very noble tree-fern, attaining a greater height than any other species, the trunk sometimes reaching a height of at least 60–65 ft.

The fronds are numerous, long, coriaceous, and arching. The young fronds and the bases of old ones are covered with soft dark-brown or black hairs. When young, as in *Cyathea dealbata*, the fronds are very much arched, but later on the stipes become shorter, or the pinnae are set

nearer the base, and the rhachis assumes a greater curve, so as to bring the frond into an almost horizontal position.

At this more mature stage of growth the fronds break at about 6 in. from their point of insertion and fall from the horizontal to the pendent position. They ultimately fall off and leave the trunk bare. (Figs. 1 (*a*) and 2.)

The lower part of the trunk is densely covered with the matted aerial roots; above, it is marked with the ovulate scars of fallen leaves, and above this again it is rough with the black stipes of old fronds.

The succulent pith, or *pitau*, used to be eaten by the natives, and, as Hooker observes, is the best food of the kind that New Zealand forests afford.

Dicksonia squarrosa.

Native name, "weki."

Habitat.—Throughout both Islands; abundant from the Bay of Islands to Dusky Bay. It is cultivated at Kew.

This is also a very handsome tree-fern. The trunk is slender, 10–25 ft. high, and covered with the persistent bases of black stipes. It is easily distinguished by the bright reddish-brown dead fronds, which hang out at all angles just previous to falling.

The trunks are used by the Maoris in the construction of their *whare-puni*.

Hemitelia Smithii.

Habitat.—This tree-fern extends farther south than any of the other species. There is a small grove at the head of Smith Sound, Auckland Islands.

This is a smaller tree-fern, more like *Dicksonia squarrosa*. The fronds are shorter and altogether on a smaller scale than those of the genus *Cyathea*. It retains its dead fronds until everything but the rhachis has decayed.

AERIAL ROOTS.

In all species the adventitious roots are an important factor in the strengthening of the trunk. When the fern is from 8 ft. to 10 ft. high there begins to form a hard black wiry mass, composed of numerous aerial roots, which covers the stem up to a variable height.

This formation of aerial roots is especially noticeable in *Cyathea medullaris*, which frequently grows on the sloping side of a valley. These roots which are given off towards the base are always most numerous on the side away from the bank, and as they grow straight down they give the appearance of a thick shaggy curtain hanging from the lower part of the stem. These roots eventually reach the ground, and thus there is formed a roughly triangular structure sometimes 7 ft. in perimeter, with its apex at a height of some 6 ft. from the ground. This mass of roots appears to act as a firm buttress to the ascending stem. Certain it is that, in the case of tree-ferns growing on a slope, the stem seldom grows straight up at first, but is inclined at an angle away from the bank, as if feeling the burden of its fronds; the buttress once firmly established, however, the fern with new energy grows up more perpendicularly.

The vitality of a tree-fern is displayed in a wonderful manner after a big burn has taken place. About six months ago fire raged through a certain piece of bush about twenty-five miles from Wellington. Desolation now prevails, but from the apices of the blackened stems of the tree-ferns

are issuing forth tender green fronds, and these tree-ferns will play an important part in the reclothing of the ravaged land. This hardiness is in all probability due to the protection afforded by the hard outer coat of adventitious roots.

EXAMPLES OF BRANCHING.

As has been remarked above, the stem of the tree-fern is generally single, erect, and columnar; but in rare instances it may become branched.

Cyathea dealbata.—There is a good specimen in the bush at York Bay. The single stem grew straight up till it was 6–7 ft. high, and then branched into two—or, rather, the branch was given off to the side, very soon, however, becoming parallel to the main stem. Both stems were of equal height and equally robust; both bore fine crowns, the fronds of one head interlacing with those of the other.

Mr. T. Kirk has recorded a remarkable instance of a branched *Cyathea dealbata* at a height of about 1,400 ft. on Ngongotaha (*Trans. N.Z. Inst.*, vol. 5). This specimen was about 9 ft. or 10 ft. high, and somewhat inclined. At about 8 ft. from the ground it divided into two branches, each under 18 in. in length; one of these was again divided, but the branches had not diverged and were growing in such close contact as to resemble rather a single branch with a double crown than two distinct branches. This singular development he attributed to the attacks of insects on the apex of the stem, leading to a division of the growing point.

Another instance was found in the tawa (*Beilschmiedia tawa*) forest at Silverstream. The trunk was about 40 ft. long, and inclined at an angle of 30° to the perpendicular. At a distance of 7 ft. from the base a branch bearing fronds was given off. About 5 ft. farther up a little crop of branches, four in number, were given off, none of them, however, bearing fronds. The main stem turned up at a distance of 20 ft. from the ground, and, growing perpendicularly for 20 ft., bore a crown of fronds. The stem itself was heavily loaded with epiphytes.

Hemitelia Smithii.—Branching is commoner in this species than in the case of *Cyathea dealbata.* The stem frequently divides at a height of 2 ft., 3 ft., or 4 ft. from the ground, the two branches growing upwards symmetrically. The specimens observed, however, occurred generally in exposed situations, or in light partially-cleared bush, and in no case did they appear very flourishing.

Mr. J. Buchanan has described a practically unique specimen (*Trans. N.Z. Inst.*, vol. 19). The tree-fern, *Hemitelia Smithii*, was 16 ft. in height, and had sixteen branches, and also several buds. The budding and branching appeared to proceed indiscriminately from any part of the stem, and this tree had several branches diverging in various directions, and these again divided as in dicotyledonous trees. From the drawing it would appear that the main whorl of branches was given off at a height of 6–7 ft. from the ground, the main axis then disappearing. The general appearance was very much like that of a cabbage-tree (*Cordyline australis*).

Dicksonia squarrosa.—Here, as in *Hemitelia Smithii*, branching into two at a height of 3 ft. or 4 ft. from the base is fairly common.

Cyathea medullaris.—I have never observed a branched specimen of *Cyathea medullaris*, nor am I aware of such a specimen having been recorded as yet.

HABITAT OF TREE-FERNS.

Tree-ferns are found in the most widely diverse situations, and are far more adaptable to varying conditions of humidity than is commonly supposed. They grow in great profusion and luxuriance in very wet rain forest, there attaining their most splendid proportions. In tawa (*Beilschmiedia tawa*) forest, on the other hand, where the ground is comparatively dry, *Cyathea medullaris* and *Cyathea dealbata* flourish not only in the valleys but also on the shoulders of the hills. Again, in beech (*Nothofagus*) forest, which, in general, covers poor and stony ground, tree-ferns are numerous, though chiefly in the valleys, which afford greater shelter and, owing to the drainage from the hills, a damper substratum. Schimper has said that tree-ferns can survive only in a very humid atmosphere, one saturated with water-vapour. In New Zealand, however, magnificent specimens of *Cyathea medullaris* are frequently found standing alone after the bush has been cleared (fig. 2). Both *Cyathea medullaris* and *Cyathea dealbata* will grow quite well in sheltered gardens. *Hemitelia Smithii* and *Dicksonia squarrosa* are common in open partially-cleared bush, and even growing actually in swamps, the specimens in the latter case, however, being rather scrubby and forlorn.

Throughout Taranaki, where almost all the land has been converted into pasture, the sunken watercourses still support tree-ferns, even when other bush has disappeared. Whether the latter has been cut down and the tree-ferns spared, or whether the tree-ferns have naturally survived, is doubtful, but I should be inclined to favour the latter alternative. It is significant that the only two species observed in these situations exposed to the sun all day were those which habitually endure the most shadeless conditions—*Cyathea medullaris* often jutting above the level of the plain, and *Dicksonia squarrosa* almost always in its characteristic clumps of rather short tree-ferns.

Groups of *Dicksonia squarrosa* are plentiful on the edges of or actually in raupo swamps in the Waitotara and Wellington districts. In the latter case, where the tree-ferns are surrounded by raupo (*Typha angustifolia*) in what must be extremely wet conditions, the *Dicksonias* look very unhappy, and, judging from their short fronds with shrivelled edges and wasted ends, one would say these were apparently "on their last legs."

VERTICAL DISTRIBUTION.

Alsophila affects the highest altitude, and is very rare in the Wellington district, though Colenso records having seen it in the beech forest of the Ruahine Ranges at 2,000 ft. and upwards.

The following observations with regard to the other species were made on the Tararua Range:—

Cyathea medullaris occurs in the rain forest of the foothills up to approximately 800 ft.

Cyathea dealbata was not very common, and its distribution was consequently less amenable to strict demarcation. Individual specimens were fairly frequent at about 1,000 ft., the last one, very poor and ragged, growing at 1,450 ft.

Dicksonia squarrosa grows to a considerable height in the bush, up to an elevation of 1,500 ft. approximately.

Hemitelia Smithii grows in considerable clumps and to a fair size up to about 1,500 ft., above which it is the only tree-fern (restricting the term

to the genera *Cyathea, Dicksonia, Alsophila,* and *Hemitelia*). From 1,500 ft. to 2,500 ft. this species occurs occasionally in patches, more often singly, but in all cases as apparently young tree-ferns with very little trunk-development—at most only up to 3 ft. The last specimens occurred at 2,500 ft., as a small bed practically on the edge of the bush. None of these looked stunted or old, but they had no trunk-development at all, with the exception of one which had a 2 ft. stem bearing a few old fronds below the crown, and no epiphytes beside a short moss.

At 2,150 ft. was quite a large bed of young *Hemitelia* mixed with *Todea hymenophylloides.* In this bed the trunks were 3 ft. to 4 ft. high.

THE TREE-FERN ROLE IN FOREST-REJUVENATION.

The banks of rivers running through bush country are generally covered with heavy rain forest consisting of many of the forest-giants of New Zealand. Very often, however, especially where there is a bend in the river, tongue-shaped areas of land are noticed bearing, instead of the typical rain forest, a distinctly secondary growth. This is characterized by the preponderance of such shrubs as *Fuchsia, Coprosma, Brachyglottis.* In amongst these are numerous tree-ferns, generally *Cyathea medullaris,* which stand out and overtop this shrub vegetation. The tree-ferns are in the main very tall, sometimes up to 60 ft., and extremely old. An explanation of such an incongruous association is demanded. In working this out I shall refer to one specific locality, though practically the same conditions obtain wherever the same factors are operative.

On the steep river-cliffs near the Otaki Forks were several patches of tree-ferns, *Cyathea medullaris,* and one in particular was studied. It was a tongue-shaped portion of the cliff, and on it grew numerous tree-ferns, 60 ft. or more in height, which indicated a great age. Among them was a secondary growth of *Brachyglottis repanda, Geniostoma ligustrifolium, Fuchsia excorticata, Schefflera digitata, Melicytus ramiflorus, Coprosma grandifolia,* and *Coriaria ruscifolia,* with an undergrowth of *Polypodium pennigerum, Polypodium diversifolium, Asplenium bulbiferum, and Blechnum lanceolatum.* This collection of plants is characteristic of the first stages in reafforestation.

Thus there were two distinct constituents of the association, differing widely in age; the tree-ferns many years older than the secondary growth. At the back and around the edges of this tongue of land was the ordinary primitive forest, consisting chiefly of tawa (*Beilschmiedia tawa*) kamahi (*Weinmannia racemosa*), and miro (*Podocarpus ferrugineus*). What is the cause of this apparent discrepancy?

No remains of logs or stumps of the previously existing forest-trees could be found on the slope. The soil is loose and somewhat stony to a depth of some 2 ft., and then the harder, more resistant subsoil is met with. It is surmised that the river cutting into the bank as it swung round the bend higher up started a crumbling-away of this loose stony top layer of soil. The forest-tree root-system on these slopes is extremely shallow, and as the "land-crumble" or falling-away of the surface layer worked back, more and more roots of the forest-trees were bared of the earth cover, until finally the trees fell into the river and were borne away. The tree-ferns, owing to their extensive and extremely fibrous roots, so held the soil that in their neighbourhood the "land-crumble" did not take place, but confined itself to the spaces between the tree-ferns. Had the slip been cataclysmic the tree-ferns must have gone into the river along with the forest-trees.

Persisting as they do, in spite of increased illumination and much drier conditions generally, they provide a shelter for the rejuvenation of the forest which is commencing as secondary growth.

In the Wainui Reserve the work of the tree-fern in assisting the renascence of the forest may be seen. Here the forest-trees have been felled and milled, while the higher undergrowth, including tree-ferns, has been left. By their protective shade the establishment of the forest-trees is made more certain.

The protective action exercised by tree-ferns is clearly seen when a road has been cut through a scenic reserve. Here the tree-ferns persisting along the sides of the road and flourishing in spite of changed conditions (fig. 3)

FIG. 3.—A newly formed road through a scenic reserve, where the tree-ferns *Cyathea medullaris* and *C. dealbata* act as a wind-break to the interior of the forest.

shelter the more delicate undergrowth and prevent what is so common in such opening-up of virgin forest—the gradual destruction of the bush by desiccation to a variable distance from the road.

TREE-FERNS IN COMPETITION FOR THE SOIL.

In many other cases, however, tree-ferns will form practically pure associations. These are fairly frequent on a small scale in ordinary rain forest or in the gullies in beech forest; but they form a striking characteristic of the bush along the Wanganui River. Here the whole side of the cliff right down to the water's edge may be clothed entirely with tree-ferns. Two questions present themselves—first, as to how the associations originated; and, second, as to why they have remained so pure.

With regard to the first, in such a locality, where the rainfall is very high, landslides are frequent. In such a case the whole face of a cliff, with all its attendant vegetation, may be carried down with catastrophic suddenness, and a clear space is left for adventurous colonists. Such tree-ferns have proved themselves to be. It is an interesting fact that tree-fern prothalli are very seldom found developing beneath older tree-ferns; they are far more often discovered in more open situations or where the ground has in some way been disturbed. This peculiarity has been observed and noted in numerous cases, and it would therefore appear probable that the exposed ground left in the wake of such a catastrophic landslide would offer suitable conditions for the establishment of young tree-ferns.

In this connection it is interesting to note an historic case of such establishment of tree-ferns on cleared land. Captain Cook, before he left New Zealand,

FIG. 4.—Grove of *Dicksonia squarrosa*, showing floor covered with the old fronds, which in this genus are dropped as soon as they are dead.

cleared a space in the bush at Ship's Cove, Marlborough, and there sowed wheat, which it was hoped would establish itself permanently. As might have been expected, it failed to do so, and a grove of tree-ferns supplanted it. The settlers in those parts still tell of how the tree-ferns came up where Captain Cook sowed his wheat.

Next as to the purity of the association: this in such a mixed forest as that typical of New Zealand is very marked. The young tree-ferns spring up close together, and their spreading fronds discourage any foreign immigration. When they are from 4 ft. to 5 ft. high the old fronds fall from their horizontal position towards the ground. The old fronds of *Dicksonia squarrosa* are dropped as soon as they are dead (fig. 4). As the fronds are generally some 6 ft. long, they cannot, when the fern is still short, hang straight down, and in consequence they are stretched out at all angles from the tree, thus covering the intervening spaces of soil. As they grow

higher some species shed their dead fronds immediately, while others retain them pendent for some time. In either case the ground is soon strewn with fronds which cover it as with a carpet, and few are the seedlings which break through and succeed in establishing themselves. The fronds, being so much larger, are far more capable of exercising a smothering action than are the small leaves of the typical forest-tree—for example, those of the beech (*Nothofagus*); also, lying as they do one upon another, instead of in direct contact with the ground, they remain free from decay for a much longer period. Thick groves of *Cyathea medullaris* permit of no undergrowth. It may be that the light which percolates through the fronds of a free-fern is too feeble to allow of much vigorous undergrowth, but when we consider the wealth of epiphytes which flourish on their stems it would seem that it is rather to their dead fronds that they owe their immunity from terrestrial competition.

THE PARSNIP AS A POISONOUS PLANT.

By B. C. ASTON, F.I.C., F.N.Z.Inst.

THE parsnip is a most favourite vegetable, and deservedly so. It is widely grown and very hardy, and in nearly every vegetable-garden may be found a patch of land occupied by this palatable root-crop. It is desired to draw attention in connection with the growth of this plant to an unusual happening, which is probably only unusual owing to all the circumstances necessary to produce the symptoms rarely coinciding. Thus, though every one grows parsnips, few allow the plant, which is a biennial, developing the root or vegetative portion the first season, and the flowers and seeds, or reproductive portion, in the second season, to grow longer than the full vegetative stage, but purchase their seeds from those who make a business of seed-production. Again, even although the cottage-gardener does allow certain plants to flower and ripen fruits, it seems necessary that the flowering or fruiting portion should come into contact with the tenderer portions of the body, such as the skin of the face and of the upper forearm, before the symptoms are able to develop. Thirdly, as my correspondent suggests, it may be necessary that small abrasions, cuts, &c., should be present. Fourthly, it may be necessary for the gatherer to be perspiring, so that the small hairs which communicate the poison to the unbroken skin should temporarily adhere. Some or all of these conditions may have to be present in the human to ensure poisoning by the plant, and there may be just as many conditions as necessary of which we cannot even guess. The above will, however, enable the reader who has "grown parsnips all his life" to refrain from scepticism and peruse the following evidence with an unbiassed mind.

The parsnip, *Pastinaca* (*Peucedanum*) *sativa*, belongs to the family Umbelliferae, which contains so many poisonous and useful plants, notably the hemlock, carrot, parsley, fennel, &c. According to Watt's *Dictionary of Chemistry* (vol. 8, pt. 2, p. 1496), the volatile oil of the parsnip contains the normal butyric ether of normal octyl alcohol, and this authority quotes

Wittstein as authority for the statement that a volatile alkaloid, pastinacine, occurs in the seeds. This is all the chemistry of parsnips which a hasty perusal of the literature at his disposal has afforded the writer. So far nothing is known of the active principle which is responsible for the following symptoms: Mr. B. M. Davis, Manager of the Moa Seed-farm, Beaumont, communicated some extraordinary effects on himself and others which he had observed after gathering parsnip-seeds. His report contains the following evidence:—

1. It appears certain that the parsnip is responsible, and that the symptoms occur only after working amongst the seeding plants.

2. In the younger stages of the seeding plant an abrasion of the skin seems unnecessary to produce a poisoning. Later slight scratches are evidently the cause.

3. The symptoms are usually a slight rash or irritation, followed either at once or later by the formation of water-blisters, which, bursting, leave pink patches possessing very distinct pores. Later these patches turn dark brown, and persist for a long time (up to one or two years).

The poisoning is not serious, there being apparently no after-effects; but since it affects some more than others the result might be bad at some time.

The following account of the poisonous effect of the parsnip is taken from an American book, *A Manual of Poisonous Plants*, by Pammel (1911):—

> Persons are often poisoned by handling the plant, which causes inflammation and vesication. Mr. F. C. Stewart, in a letter to the writer, states that in one case the eyes became swollen; vesication occurred from poisoning caused by the flowers.

The above case and some others are also referred to on page 663 again, as follows:—

> That the parsnip does at times produce dermatitis has been proven. The following very interesting letter from Professor F. C. Stewart, botanist of the New York Agricultural Experiment Station, is of interest in this connection:—
>
> "I recollect that some fifteen years ago you were very much interested in the reputed poisonous properties of the wild parsnip, and that you had reached the conclusion that the wild parsnip is not poisonous. I think you may be interested to know of an instance which has recently come to my attention. Henry Van Dresser, a prominent lecturer on poultry in this State, last season had a very serious injury to his face and eyes. His face became badly swollen, and his eyes were in a terrible condition. It was feared at the time that they would be ruined, but the sight was not lost, although it was considerably impaired. The physician in charge diagnosed it as a case of poisoning, due probably to the flowers of wild parsnip. Very shortly before the trouble appeared Mr. Van Dresser had been mowing a large patch of wild parsnip which was in bloom. It was a hot day, so that he perspired profusely. He gathered bunches of the wild-parsnip plants in his arms and carried them. This brought the plants in contact with his face. Both Mr. Van Dresser and the physician feel confident that the wild parsnip was the cause of the trouble. Another gentleman who heard of this case told me that some years previously he had lost a little girl with poisoning of a somewhat similar character, and it was attributed to the parsnip-blossoms, among which the little girl had been playing immediately before the attack."

In a little book by David Ellis, *Medicinal Herbs and Poisonous Plants* (London, 1918), the cow-parsnip (*Heracleum sphondylium*) is credited with the poisoning of some workmen in Belgium employed in collecting the plant:—

> They had been employed to root it out from a certain park. This was done in the early morning at a season of great heat. All experienced intense heat on the left arm and wrist. Inflammation followed, accompanied by sores which prevented them from returning to work for nearly three weeks. In collecting the plants they had thrown them over their left arm.

A GUIDE IN PLANT ECOLOGY.

Practical Plant Ecology, by A. G. Tansley, M.A., F.R.S. 228 pp., with 15 text-figs. London: George Allen and Unwin. Price, 7s. 6d. net.—Though prepared primarily for the student in Great Britain beginning ecological work, this book should be of value to New Zealand students also. It is written with its author's customary clarity and breadth of view, and succeeds in its aim of being a "guide for those who are attracted to ecological work but are uncertain as to how to set about it." Part I discusses the scope of plant ecology, and rightly insists that ecology is "more a means of approach to a large part of detailed botanical study than a name for a special branch of the subject." The fundamental importance of field-work is strongly emphasized. The chapter on "Natural and Semi-natural Vegetation" should be read by the local student concurrently with the more logical and thoroughgoing treatment of Cockayne in his *New Zealand Plants and their Story* (2nd ed., chap. x). Part II deals with the structure, distribution and development of vegetation. A brief but well-proportioned treatment of general conceptions is followed, and illustrated by a summary outline of existing British vegetation. Here, again, the local student will find it a valuable exercise to compare the usage of terms with that of Cockayne. Part III, on the methods of studying vegetation, follows conventional lines, but the viewpoint is eminently sound, and there occur dicta that others than admitted beginners might well ponder—*e.g.*, "Quantitative data are not *necessarily* of any value, and we must never make a fetich of them"; "the student should never allow himself to become enslaved by his *methods*." A useful chapter on methods of charting vegetation contains the reminder of the danger of "making the graphic record the end in itself." Part IV gives an excellent general account of the factors of the habitat, and their measurement, the habitat being defined as "the sum of the effective conditions under which the plant or the community lives." Part V contains a refreshing and suggestive treatment of the place of ecological work in schools. This part can be strongly recommended to teachers, and especially students in our training colleges. Were nature-study and botany studied and taught on these lines, rather than on those of the text-books at present in vogue, the results would be much more satisfactory, and there would be less of that distressing bandying of ill-digested technical terms, which, in Thring's words, "pretend to be knowledge, and are like shut doors proudly labelled 'Museum,' which if any daring explorer opens, he finds behind nothing but cobwebs and dust, and the doorkeeper asleep with the key in his pocket."

The appendix contains sections on life-forms, survey-methods, photographing vegetation, and specific acidity, and one on the determination of carbonates and chlorides in soils, by Dr. H. J. Page, of the Rothamstead Experimental Station. The classified list of papers on British vegetation might, perhaps, have been used to advantage in a brief discussion of the methods of utilizing the literature of special topics.

H. H. A.

PAN-PACIFIC FOOD CONSERVATION CONFERENCE.

HONOLULU, 31ST JULY TO 14TH AUGUST, 1924.

THIS Conference, which will be held under the auspices of the Pan-Pacific Union, in Honolulu, from the 31st July to the 14th August, 1924, will comprise the following groups :—

(1.) International agreements regarding fisheries.
(2.) Economic entomology.
(3.) Plant pathology.
(4.) International quarantine policies.
(5.) Crop production and improvement.
(6.) Forestry.
(7.) Climatology.
(8.) Transportation and distribution of food products.
(9.) Topography—land and sea.
(10.) Animal husbandry.

It will be seen that the range of the above subjects is most comprehensive, and includes most branches of knowledge which are of vital interest to New Zealand producers and to those engaged in giving scientific advice.

The Director, Mr. A. H. Ford, is anxious to obtain papers to be read before the Conference, in plenty of time to have them printed for circulation at the meetings. The undersigned will be pleased to receive the titles of any papers which authors may wish read, or the papers themselves.

A few copies of the *Bulletin* of the Pan-Pacific Union are received each month, and a specimen will be sent to any one interested in the work of the Union. The Honorary Presidents of the Union include the Presidents of the United States, China, and of the House of Peers, Tokio ; the King of Siam ; and the Prime Ministers of Australia, Canada, and New Zealand.

Any further information available will be supplied on application to

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The above have been written by Mr. Elsdon Best, F.N.Z.Inst., the well-known authority on Maori life, institutions, and customs.

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THE NEW ZEALAND

JOURNAL OF SCIENCE & TECHNOLOGY,

VOLUME VII, No. 1, 1924.

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NOTICES.

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SURVEY OF THE FIELD OF RADIO COMMUNICATION.

By A. GIBBS, M.I.E.E.

THE electrical engineer is familiar with the fact that a live transmission-line is surrounded by electric and magnetic fields of force. Telephone engineers are sometimes rather painfully aware of this fact when irregularities in the power network cause interference in adjacent telephone-lines, due to the abnormal fluctuations of this field of force and its linkage with the telephone-wire system. Although such influences may extend for a considerable distance in the case of extra-high-tension transmission-lines and heavily loaded networks, the intensity of the normal induction field falls off rapidly with distance in accordance with the inverse-square law. These fields may be regarded as intimately associated with the current-carrying wire, alternately extending out from and collapsing upon it, and under such circumstances only a negligible portion of this field becomes detached from the power system. There are, however, occasions, such as when arcing takes place at a faulty insulator, when the electrostatic charge upon the surface of the transmission-wire is suddenly and intermittently discharged to ground. These rapid alternations of charge and discharge cause surges, or oscillations, in the power-wire system. The energy of the field associated with the power wires is not now given sufficient time to collapse entirely upon the conductor between discharges, and a portion of it is propagated through space in the form of electro-magnetic waves, the frequency of which corresponds to the frequency of the oscillations set up in the power network.

This brings us to the problem of the radio engineer, which is to create in an overhead system of wires (commonly called an " aerial " or " antenna ") alternating currents of great frequency (called " oscillating currents "), so that the energy of the field associated with the oscillating antenna system may be detached therefrom and utilized in the form of electric waves radiated into space.

The overhead antenna system, with its rapidly alternating charges of electricity, may be likened to a miniature sun, whose mass of rapidly vibrating electrons influences the medium enveloping it, and causes electric waves to spread out in all directions. The waves used in radio signalling are fundamentally the same as light waves, and differ from them mainly in their much lower frequency, and consequently much greater wave-length. They are therefore related to them in somewhat the same manner as a low note is related to a high-pitched one, the difference being one of frequency.

There are two classes of waves used in radio signalling, termed " damped " and " undamped " waves. The undamped waves (commonly known as " continuous waves ") are of uniform frequency and amplitude. The damped waves (commonly known as " spark transmissions ") are of uniform frequency, but fall away rapidly in amplitude, so that the first few waves of a wave-train are practically all that are available for signal purposes at the receiving end.

The damped wave resembles a sharply struck piano-note, while the continuous wave might be likened to a steadily and uniformly bowed violin-note. The one falls away rapidly in amplitude, while the other persists steadily and uniformly.

Continuous waves possess great advantages from a signalling point of view over damped waves, as, their amplitude being maintained at a constant value, the effect upon the receiving aerial of each wave in the train is cumulative.

Damped waves are produced mainly by spark transmitters, which have done duty in various forms since the earliest days of wireless telegraphy, and have apparently reached the crest of their development in the tuned spark-discharger.

In the early days of spark or damped-wave telegraphy it was recognized that the slower the rate of decay of the oscillations the more efficient were the results obtainable, and that the ideal to be sought was a case in which the damping would be zero—*i.e.*, where the oscillations could be maintained continuously.

Among the advantages to be derived from the use of continuous waves are the following :—

(1.) Larger amounts of energy can be generated and radiated.

(2.) The absorption due to the passage of continuous waves over land and water is less than for damped waves.

(3.) Interference between transmitting-stations can be reduced, due to the sharper tuning that can be attained with continuous waves, and for the same reason more frequency (or wave) channels can be made available.

(4.) Greater sensitivity can be obtained in the receiving apparatus.

In 1900 it was shown by Duddell that if an arc between two carbon electrodes be shunted by an oscillating circuit consisting of inductance and capacity in series, the arc could become a source of continuous oscillations. These oscillations were only, however, of audible frequency, and were therefore unsuitable for radio-telegraphy purposes. Later developments due to Poulsen, such as burning the arc in a hydrogenous atmosphere, the introduction of a magnetic field, the use of a copper water-cooled anode, and a rotating carbon cathode, enabled oscillations of radio-telegraphic frequency to be generated.

In the second method of generating continuous waves the high-frequency oscillations are produced primarily by a high-frequency alternator, which, by reason of its high speed of rotation (20,000 r.p.m. in some cases) and its multi-pole construction, is capable of producing alternating currents of 100,000 periods per second. In this case the frequency is dependent not upon the constants of an associated oscillating circuit, but on the speed and construction of the alternator itself.

A third method of producing continuous waves is by means of the thermionic valve, or vacuum tube. This valve consists essentially of an evacuated bulb containing three electrodes; a cathode, consisting of a filament heated usually to incandescence by means of an electric current; an anode, usually in the form of a metal plate surrounding the filament; and a grid, which usually takes the form of a spiral of wire surrounding the filament, and placed between the filament and the anode or plate. The incandescent filament emits electrons, which may be drawn to the plate by applying a positive potential to the latter. The resulting plate-current may be varied at will by altering the potential of the grid with respect to the filament. A positive potential on the grid will cause a marked increase in the anode current, while a negative potential will cause the grid to repel electrons on their way to the anode, thus decreasing the plate-current.

The three-electrode valve is capable of generating continuous oscillations, for, just as a swinging pendulum, if given taps at the right moment, may be supplied with energy equivalent to that lost in friction, and so be maintained in oscillation, the grid and plate circuits of the valve may be so related that the energy lost, for example, in an oscillating circuit connected to the plate, may be compensated for by drawing upon another circuit associated with the grid and magnetically coupled to the plate circuit. The necessary energy is supplied by a local power system. This is one of the many methods in which continuous oscillations may be generated by a vacuum tube and its associated circuits.

FORMS OF TRANSMISSION.

Morse Code.—Telegraphic signals composed of the dots and dashes of the Morse code may be produced by generating short trains of waves corresponding with the dot, and longer trains corresponding with the dash; thus code signals consisting of wave-trains, of short or long duration, and with the various permutations of the Morse code, may be propagated through space. This may be regarded as a form of modulation, the energy fluctuating from zero to a maximum as the antenna is either quiescent or charged with high-tension high-frequency oscillations.

Radio-telephony.—For radio-telephony, continuous waves are necessary, so as to avoid the undesirable gaps between the discrete trains of damped waves. The production of the continuous waves may be effected in many ways, as already indicated.

The main problem of radio-telephone transmission is so to modify or modulate the amplitude of this continuous stream of waves that, instead of retaining their uniform amplitude, as in the case of continuous-wave telegraphy, they may become electrical counterparts of the sound waves they are called upon to transmit.

This modulation is somewhat analogous to what takes place in a land telephone-line, but, in the case of the line, changes are produced in the amplitude of an electric current. These changes in the form of the current

are produced by the agency of the telephone transmitter, which is in reality a variable resistance capable of varying the current which passes through it in accordance with the movements of its diaphragm, this in turn being under the control of the sound waves that impinge upon it. The currents in the land line are thus electrical copies of the sound waves so far as their delicate variations of amplitude are concerned. At the far end of the line they are passed through an electro-magnet which constitutes the ordinary telephone receiver. Here they produce changes in the magnetic field which synchronize with the changes taking place in the electric current. Thus the varying magnetic field causes the diaphragm of the telephone receiver to execute vibrations corresponding to those of the distant transmitter. The air in the vicinity of the receiver diaphragm is therefore thrown into vibrations of feebler intensity, but of similar form, to the sound vibrations impinging upon the distant transmitter.

In radio-telephony we modify high-frequency currents (or oscillations) by means of the modulated currents which are produced by the telephone transmitter; but the operations resemble one another in that the resultant stream of high-frequency waves has been varied in amplitude or intensity in strict accordance with the variations of the sound waves.

In the early days of radio-telephony this variation of amplitude was effected by placing the transmitter (a variable resistance) directly in the antenna in which the continuous oscillations were being developed. As the transmitter varied in its resistance in accordance with the movement of its sound-controlled diaphragm, so the amplitude of the oscillations in the antenna was varied in strict accordance with the variations of amplitude of the sound wave. This method is now adopted only in very small-power transmitters. In larger transmitters different methods have been rendered possible by the use of the vacuum tube.

RECEPTION OF ELECTRIC WAVES.

It was early found that a good radiator of electric waves, such as an antenna, was a good absorber of such waves. The antenna at the receiving station is therefore capable of absorbing a portion of the energy of the passing wave, and of reproducing oscillations similar in form to but naturally weaker in intensity than the oscillations in the transmitting antenna.

The problem of reception is to convert the high-frequency oscillations in the receiving antenna into low-frequency electric currents similar in form to the modulated high-frequency oscillations, and therefore capable of influencing the diaphragm of a telephone receiver or actuating any suitable receiving device.

Before the introduction of the valve receiver, the coherer and the crystal were used as detectors or rectifiers of this high-frequency energy. This the crystal detector was able to perform by reason of its property of unilateral conductivity—*i.e.*, conductivity for electric currents in one direction only. The crystal, although somewhat erratic, was an efficient detector of undamped waves, for by suppressing, say, the positive portion of each oscillation cycle the energy of each wave-train could be integrated by a storing device, such as a condenser, and delivered as a single pulse through the electro-magnet of a telephone receiver. As, in a spark system, the number of wave-trains corresponds to the number of spark discharges, or series of oscillations, at the distant transmitter, a note could be heard in the telephone receiver corresponding in pitch to the spark frequency of the distant transmitter.

The crystal detector could not, however, deal with the continuous-wave situation without the introduction of a device, at one end or the other, for cutting up the continuous waves into groups or trains that could be integrated in the manner just described.

The valve has superseded the crystal as a rectifier, on account of its greater robustness and reliability. The valve is capable of rectifying high-frequency oscillations in more ways than one. In all cases the received oscillations are impressed upon the grid, and are made to produce an audio-frequency variation in the anode or receiver current. The valve has the added advantage that it can be used to amplify the received signals, and can also be used for the reception of continuous waves, without the necessity of breaking them up into groups. In fulfilling the latter function the valve is arranged as a low-power generator of continuous oscillations, the frequency of which differs slightly from that of the received oscillations. An interference effect is thus produced, and the resultant oscillatory current rises to a maximum, and decreases to a minimum, at predetermined intervals. The regions of maximum amplitude are known as "beats," the amplitude of these beats equalling the sum of the individual amplitudes of the two sets of oscillations. The frequency of these beats may be adjusted to any value by varying the locally generated frequency. These high-frequency beats are rectified by the detector in the usual way, producing an audible signal of the beat-frequency in the telephones.

Radio-telephone Broadcasting.

What has now come to be known as "broadcasting" consists in the transmission by radiophone of music and speech — entertainment and instruction—of all descriptions, which can be picked up by "listeners-in" whose receiving equipment brings them within its range.

Remarkable progress has of late years been made in the quality of broadcasting transmissions and in the efficiency of receiving apparatus. Upon the broadcasting transmission plant is imposed the task of transforming the speech energy of audio frequencies into electrical energy of radio frequencies, and this must be done in such a way as to cause as little ultimate distortion as possible. To the telephone engineer is due a great deal of the credit for the production of apparatus which will permit the various transformations of energy to take place with a minimum of distortion, and this in spite of the fact that all apparatus of an electrical character through which current flows tends to distort speech to a greater or less extent. It is fortunate, however, that the medium through which the carrier waves are propagated is, unlike the land telephone-line, distortionless in its effect upon the modulated high-frequency waves. Modern apparatus is also capable of producing what may be regarded as a pure carrier wave: the whole difficulty lies in the art of modulating that wave in strict accordance with the impressed audio frequency speech or music, and at the receiving end demodulating it so that the received speech or music may be perfectly true and natural.

The demands on a broadcasting transmitter, which, in addition to the transmission of speech, must transmit music from all classes of instruments, either separately or in combination, are much more severe than those imposed upon a transmitter which is concerned merely with the transmission of speech. Speech can be transmitted with frequencies ranging

from about 400 to 2,400 vibrations per second; but for the satisfactory transmission of music a much greater range of frequencies is necessary, and the modulated wave is still more complex.

Even with a perfect broadcasting-station the problem is not altogether solved, because the radiated energy has to be converted back into sound waves by the receiving-station; and the use of apparatus such as telephone receivers, loud speakers, and transformers, that are imperfectly designed, and circuits which do not amplify all frequencies alike, may entirely mar the most successful broadcasting efforts, and create interference with other listeners in the neighbourhood.

Broadcasting had its origin in the United States of America, and there are now about six hundred broadcasting-stations and two million listeners-in in that country. The Government participates in the scheme by sending out market and stock reports of all descriptions for the benefit of the farming community, time-signals, and even calibration signals, so that receiving-stations may accurately tune their receivers to pick up different stations operating on different frequencies. These broadcasting-stations are operated and maintained by widely varied interests—by those interested in the radio business and hence in the sale to listeners-in of receiving equipment, by Press agencies, churches, universities, and businesses of all kinds —the last for the sake of the publicity afforded.

In conjunction with land toll lines these radiophone broadcasting-stations have been used on great public occasions to transmit the human voice simultaneously to millions of people located in their homes and in great assemblies and scattered all over the States.

In the United Kingdom broadcasting has been in existence for less than two years. It is rapidly being established upon a firm basis, and is assuming a high order of excellence. It is controlled, under agreement with the Postmaster-General, by a combination of British radio manufacturers and dealers known as the British Broadcasting Company, and the annual charges are met by taxes upon sales of radio receiving apparatus and by the indirect subscriptions of listeners-in through the medium of the license fee. The number of licensed listeners-in is now about 750,000, and this number is rapidly increasing.

The programmes transmitted are such as to suit all tastes—operatic and song; classical music and jazz music; weather reports and wireless hints; talks on theology and tips from the stables; scientific lectures and children's stories; chats on puddings and pies; commerce and Shakespeare—in fact, all the multitudinous subjects that interest humanity.

What is known as "simultaneous broadcasting" has been effected with satisfactory technical and economical results. Between 6 p.m. and 6 a.m. London is connected by wire toll lines to all the broadcasting centres. By this means a part of the evening programme from any station may be sent by land line to all the broadcasting-stations, and simultaneously broadcasted by them to their respective districts. In this way the London news bulletin is nightly transmitted by the one speaker in London, who simultaneously operates the broadcasting-stations at London, Bournemouth, Birmingham, Cardiff, Newcastle, Manchester, Glasgow, and Aberdeen. The saving in professional expenses by the simultaneous broadcasting of entertainment is obvious. Arrangements are in hand for the opening of what are known as "relay stations," operating on the principle just described, whereby smaller satellite broadcasting-stations may receive by wire line, and retransmit by radio, the programmes of their parent stations. This

brings the benefits of the scheme within the reach of those in remote areas and equipped with simple receivers which would otherwise fail to pick up the more distant transmissions.

A recent development has been the picking-up in England of programmes broadcasted by an American station, amplifying, and retransmitting them from the Manchester broadcasting-station. The possibilities in this direction are of great interest.

In New Zealand, broadcasting has so far been carried out on low power and in a comparatively desultory manner. Considerable praise is due to those who have initiated this development, and for the efficiency obtained on the low powers, and still lower financial support, available. The full possibilities of broadcasting will only be realized when the scheme is placed upon a proper technical and financial basis, which is contemplated in the near future.

With the improvements that are rapidly taking place in transmission and reception it is not unlikely that the broadcasting-station, adequately supported by patrons' subscriptions, will ultimately become the leading agency for the dissemination of entertainment and of educational instruction.

Broadcasting is also calculated to be of the greatest service to the remote settler, bringing the best entertainment the city can afford to his fireside, and keeping him informed of the latest developments in the centres of population.

Interesting experiments have been made in the United States, and more recently in the United Kingdom, in the broadcasting to schools, from a central bureau, of educational lectures on special subjects. The schools have been equipped with loud speakers, and considerable success has been reported. The scheme of giving educational lectures by specialists from a central source, and of broadcasting them to scattered audiences in less favoured situations, has many possibilities, and possesses considerable public and economic advantages. In this connection it should be mentioned that the programmes of the British Broadcasting Company comprise a proportion of short talks on educational subjects. Experts in all branches of activity have willingly given their services for short talks of an instructional character, and the interest manifested in this part of the programme is said to be of a highly encouraging order.

The international significance of broadcasting is worthy of passing notice. Already, as previously mentioned, American programmes have been picked up in the United Kingdom and retransmitted from one of its broadcasting-stations. There is every prospect of reciprocity in such matters between adjacent countries. With the rapid increase of listeners-in in all countries of the world the psychological effect of such an interchange of broadcasting can easily be imagined. It is not perhaps too much to say that international radiophone broadcasting, combined with the ever-widening activities of radio amateurs and experimental societies, will contribute its quota towards creating and cementing those ties of brotherhood which it is the aim of the League of Nations to promote.

AMATEUR STATIONS.

Apart from the listener-in to broadcasting, the growth of amateur or experimental stations in many countries of the world is worthy of comment. It is now accepted that in the public and strategic interests such stations must be licensed and controlled, otherwise a serious menace would exist in

time of war or other emergency, and the operation of coast and ship stations in times of peace would be seriously affected. Moreover, such stations are a menace to one another unless reasonable restrictions are observed.

Apart from this aspect, it should be of some interest to electrical engineers that such large numbers of people should be interesting themselves in the fascinating study of high-frequency transmission and reception. Radio-telephony, through the agency of broadcasting, is having an effect upon the public that no other branch of electrical work has hitherto produced. Intelligent curiosity has been aroused in the subject of electricity, and may yet become a very important thing for electrical progress in general. The understanding of electrical principles, and the familiarity with electrical problems thereby engendered, must in itself do much to popularize the use of electrical appliances, and create a market for the utilization of electrical energy, which, in this country at any rate, with its hydro-electric development, is a highly desirable feature.

Another aspect of such experimental work is of considerable national importance. It is generally recognized that, should the world ever again be burdened by a great war, electrical communications, and particularly radio communication, would be of even greater importance than in the past, and there would be an increasing demand for radio signallers. In the United Kingdom, the United States of America, and other countries very great use was made of the services of amateur wireless signallers in the Great War, and a body of skilled workers in this field must, under such circumstances, be regarded as a national asset of considerable value.

IRREGULARITIES IN THE MEDIUM.

The medium through which electric waves are propagated is subject to considerable variation in what might be termed its transparency or wave-propagating characteristics. In addition to this want of constancy, it is continually being agitated by natural electrical disturbances, which give rise to electric waves called "static" or "atmospherics," which constitute a source of interference with the reception of legitimate radio signals. At this stage it will be appropriate to say a few words about the various propagation difficulties.

Fading.—It sometimes happens that the same receiving equipment will one evening have difficulty in picking up a short-wave station fifty miles distant, and on another evening easily receive stations over a thousand miles distant. Even when reception is good, striking variations in long-distance short-wave signals may be observed from minute to minute, and even from second to second. Such variations have come to be known as "fading." Their effects are most marked with long-distance short-wave signals during the hours of darkness.

Diurnal and Seasonal Variations.—Allied to the subject of "fading" is that of diurnal and seasonal variations of signal-strength. Recent actual observations in waves as long as 5,000 metres transmitted across the Atlantic between the United States and the United Kingdom showed at times a ratio of 15 to 1 in night and day signal-strengths, and this ratio is greatly exceeded when using higher frequencies (shorter wave-lengths). Seasonal variations are also familiar to all observers, winter reception intensities greatly exceeding those of summer. Reduction in signal-strength

is also felt when the sunset condition intervenes between the sending and receiving stations, and when the route is over deserts, &c.

The effects referred to are not fully understood, although various theories have been evolved, some of which are strongly supported by mathematical considerations. A widely accepted hypothesis is that wireless waves are conducted or reflected around the earth through our atmosphere (a more or less insulating medium), between a semi-conducting earth and an electrically charged semi-conducting layer or layers in the upper atmosphere, generally referred to as the Heaviside layer. Owing to the effects of sunlight upon the rarefied gases of the upper atmosphere, the insulating medium (the atmosphere) is penetrated, during daylight, by positive and negative ions. This causes a loss to some extent of its insulating properties, and considerable absorption takes place, especially in the shorter high-frequency waves. This accounts to some extent for the inferior daylight transmission. During the hours of darkness, ionic recombination takes place and absorption is reduced. Also, an improvement takes place in the sharpness of definition of the under-surfaces of the upper semi-conducting layers, but they are liable to undergo considerable variation. Unequal reflection and refraction are thereby occasioned, causing the diversion of a varying portion of the wave energy, and interference effects. Such a theory accounts for much of the variable signal phenomena experienced.

On the other hand, the opinion is gaining ground that the whole phenomena of fading and regular variations in intensity may be attributed to variations in the absorption coefficient of the medium rather than to reflection and refraction effects from the Heaviside layer. We are, however, forced to fall back upon this layer for an explanation of the large errors in bearings observed by direction-finding stations when operating at night over long distances. Could these difficulties be removed, the greater radiation efficiency of the shorter waves could be more largely availed of, and considerable economies in power consumption effected.

Atmospherics.—The shorter waves are also more desirable, because they are less distributed by atmospheric strays, the intensity and number of such disturbances increasing with the wave-length. Thus, while long-distance stations are forced to use long waves on account of the greater absorption and variability of shorter waves, these long-wave stations are more greatly disturbed by atmospherics. The subject has received and is receiving the closest attention and investigation by scientists and radio engineers in all countries, as befits its importance.

LONG-DISTANCE RADIO-TELEGRAPHIC COMMUNICATION.

Trend of Recent Developments.—The use of spark transmissions for long-distance working is no longer considered, on account of the greater all-round efficiency of the continuous wave. There are three independent lines of development in connection with continuous-wave high-power transmitters—(1) the arc, (2) the alternator, and (3) the valve or electron tube.

The Arc.—The great improvement in the reception of continuous waves made possible by the oscillating-valve receiver gave a great impetus to the arc transmitter, which to-day handles a great part of the world's long-distance radio traffic. Some of the advantages claimed for the arc are simplicity of manipulation, flexibility in wave-length, reliability, and cheapness of upkeep. Its weak points are comparatively low efficiency—30 to

40 per cent., not including power plant—and an impurity of wave which causes it to interfere with transmission on shorter waves and to emit harmonics of the fundamental wave. Recent experiments have shown that harmonics can be largely eliminated by loose-coupling the arc to the antenna, although some loss of power is thereby occasioned. Its possibilities for radio-telephone communication on the larger powers have not yet been practically demonstrated.

Arcs of powers varying from 100 kw. to 1,000 kw. are installed at such places as Annapolis, Balboa, Darlington, Long Island, San Diego (U.S.A.); Guam; Honolulu (Hawaii); Cavite (Philippines); Eiffel Tower, Bordeaux, Lyons, and Nantes (France); Horsea and Oxford (England); Abu Zabal (Egypt); and Coltano and Rome (Italy).

The Alternator.—Wireless alternators are all of the inductor type, and have developed along two main lines—medium and high frequencies. The Telefunken (German) alternator does not directly develop radio frequency. It runs at a comparatively slow speed, has fewer poles than its rivals, and depends for the production of the radio frequency upon static frequency-doublers. The greater reliability of the slower-running machines is an advantage, but only multiples of the machine frequency may be obtained by means of the frequency-doublers.

There are two other principal types which, by means of great speed of rotation and the use of multi-poles, develop directly the required radio frequency: these are the Alexanderson (Radio Corporation of America) and the Latour (France). They are inherently restricted to long-wave operation, but have interesting possibilities for high-power radio-telephone working. High-power stations of these types, ranging from 200 kw. to 1,000 kw., are to be found at such places as Long Island, Marion, New Brunswick, Tuckerton, Bolinas, Long Island (United States); Kahuku (Hawaii); Lyons and St. Assise (France); Hanover and Nauen (Germany); Carnarvon (England).

The alternator has a higher over-all efficiency than the arc (35 to 50 per cent.), has a purer wave, and may be used in parallel for production of high powers. Its initial expense is greater than that of the arc, and in construction it is less rugged than that of slower-speed generators.

The Valve Transmitter.—This transmitter is beginning to invade the high-power field. The present difficulty is in the construction of robust units of any considerable power, but a great deal of research and experiment work is being done in this direction in many countries.

One of the problems of the high-power valve is in the dissipation of the heat liberated by the plate, or anode, and absorbed by the walls of the containing-vessel. Hard glass was originally used, and this is being replaced by such refractory substances as quartz and silica. Various applications of water cooling to the containing-vessel and the anode have been devised. By such means powers up to 100 kw. have been produced in a single valve, but little information regarding the operation of the sizes above 10 kw. to 20 kw. is available.

While our knowledge of the performance of high-power electron tubes is limited, they have qualities which constitute them serious rivals of the arc and alternator. They have the highest over-all efficiency, are extremely flexible as to power-grouping and wave-length change, lend themselves to radio-telephony, and give a very pure note at the receiving end. Against these advantages must be placed a probable high cost of upkeep, harmonic

emission, and the difficulty so far in producing them commercially in units above about 10 kw. to 20 kw.

At Carnarvon a battery of medium-power valves giving a total of 260 kw. has been used for some time as a transatlantic transmitter, with results that are said to be entirely satisfactory as regards both general efficiency and life.

Directive Reception.—Attempts at solving the problems of uninterrupted long-distance radio communication have mainly been along the lines of enormous power and high antenna structures, and schemes are now in hand for distances of the order of 6,000 or 7,000 miles, using towers 1,000 ft. in height and powers of from 1,000 kw. to 2,000 kw. The explanation of these ponderous methods no doubt lies in the eccentricities of the medium, the unsolved problems of atmospheric interference, and the squandering of radiated energy by the broadcasting methods which so far have prevailed. Beyond the distances at present achieved as commercial successes—say, 6,000 miles—it is questionable whether a continuance of such methods is commercially practicable. Doubling the transmitting antenna current—*i.e.*, quadrupling the power—can only double the telephone current at the receiving end. Any small improvement which will double the strength of the received signal in comparison with the atmospheric disturbances therefore accomplishes as much as quadrupling the power of the sending-station.

The increase of signal-strength gained by amplification unfortunately increases any atmospheric disturbances to a like degree, and the ratio of signal-strength to disturbance is not altered thereby, although some small improvements in amplifying methods have been effected by which the atmospheric signal may be partially suppressed, without correspondingly reducing the signal-strength.

Anything that will independently increase the signal or reduce the disturbance will do much towards improvement in long-distance communication. A vast amount of work has been done towards achieving this result. Hundreds of circuits have been devised and devices tested, but mainly with unsatisfactory results. The use of closed coil antennae and buried wires has contributed appreciably towards the desired end. Audio frequency tuning of the telephone circuit, and the development of filter circuits, have also assisted, but these methods do not give the desired margin of safety against severe atmospheric conditions. Where the direction of atmospheric interferences is fairly constant, and differs from that of the transmitting-station, great assistance has been gained by unidirectional reception methods. One of these employs the principles of direction-finding, and uses a combination of ordinary overhead antenna and a closed loop, which gives a reception curve of the heart-shaped variety. If the general direction of atmospherics at the receiving-station happens to coincide with or approximate to that of zero reception, great increase of the signal-to-static ratio results. One such favoured spot exists near San Francisco and another near San Diego. At the former, the use of such directional reception has increased the signal-to-static ratio twenty to thirty times, and has made it possible to dispense with the Honolulu relay station, and to receive direct from Cavite, in the Philippines, over 6,000 nautical miles distant, without " shut-down " periods due to static interference. The antenna current at Cavite is 200 amps.—only one-third of what is used at a number of modern high-power stations. The discovery of such a spot in the north of New Zealand is not unlikely, and would greatly simplify the reception work of a long-distance station.

Another such development—the Beverage antenna—is of similar application. It consists of a long, low antenna pointing towards the transmitting-station. Its efficiency depends upon similar relative conditions to those just referred to, the signal building up to a maximum at the receiving end, and the static at the other.

Directional transmission is another hopeful line of development which, so far, has been practically confined to waves of high frequency—*i.e.*, short wave-lengths. Such waves can be reflected and focused into a beam by wire structures of parabolic form. Unfortunately, such short wave-lengths suffer considerable absorption. The method does not lend itself to the long-wave transmissions which have so far been found necessary for great distances, but promises to do much to economize power over short and medium distances.

IMPERIAL CHAIN PROPOSALS.

The recent decision of the United Kingdom to proceed with the erection of high-power stations capable of Empire communication brings the realization of an Empire chain within measurable distance. The existence of such a chain of stations capable of direct communication at high speed and reduced rates would confer great commercial, social, and political advantages, and would facilitate the conduct of business and the interchange of many matters of mutual interest at present relegated to our ocean mail-services. The first of two such stations is now being erected at Rugby, alongside the great Roman Road—the one-time hall-mark of long-distance communication. Twelve masts, each over 800 ft. in height, and spread over about 900 acres, will be erected. The transmitter will be of the valve type, and the antenna oscillating energy will reach 500 kw.

NEW ZEALAND IN RELATION TO HIGH-POWER DEVELOPMENT.

Signals from practically all the high-power wireless telegraph-stations in the world, as well as many of moderate power, have been received in New Zealand during daylight hours. Judging by such results, it seems safe to conclude that, in spite of its remoteness, New Zealand is well situated for satisfactory radio communication with the great centres of the world. It seems probable that during a considerable portion of the twenty-four hours countries such as South Africa, East Indies, China, Japan, United States, and Canada—all within, and some well within, 7,000 miles—could be reached on medium power. Lying between the ranges of 7,000 and 11,000 miles are such countries as Egypt, Europe, the eastern United States of America, and the United Kingdom. The upper limit of these ranges eclipses anything yet attempted on a commercial scale by wireless telegraphy, and imposes a severe strain upon the resources of modern radio engineering, especially when it is considered that, from a strategic as well as an economic standpoint, a high degree of reliability would be required in order to maintain traffic schedules satisfactorily.

The most important centre with which New Zealand communication is desired, the United Kingdom, is, unfortunately, at the great distance of over 11,000 miles. It is, however, fortunate that the shorter great-circle distance between New Zealand and the United Kingdom is an ideal wireless route. An inspection of the globe will show that it is practically a clear sea and ice route all the way. The route referred to is northwards from New Zealand, over the North Polar region, and on over the North Sea to England.

The high-power wireless station need not be regarded as an undesirable competitor of the submarine-cable system, but rather as supplementary to it. It has always been the experience in connection with electrical communications that increased facilities and reduced delay mean increased traffic, the more so if rates can at the same time be reduced.

The radio-station possesses certain inherent advantages over the cable. Its operation and maintenance are centralized, and it is therefore more readily adjusted and controlled. It has a remarkable flexibility of operation, being able to communicate not with one fixed point only but with all points of the compass. This reduces relaying or retransmitting to a minimum. With a prearranged traffic schedule designed to use the most favourable hours for communication with reciprocating stations it permits a wide range of communication. It is not easily deranged in times of war, whereas cables can readily be cut. It is able to broadcast—if it be powerful enough—to all parts of the world simultaneously, thus possessing a unique facility for economically propagating news of common interest, such as Press communications. It can also transmit the human voice, which long cables cannot at present achieve owing to excessive attenuation. It is capable of high-speed telegraphy; but in this respect the cable is fast making headway.

There are, however, a number of disabilities under which a radio-station labours in comparison with a cable service, and these disadvantages indicate that the long-distance radio service should be regarded as complementary to the cable service. There is a lack of absolute secrecy—although this is being overcome over medium distances by high-speed transmission, and by special apparatus for rendering transmission unintelligible in the absence of suitable translating devices; and directive transmission has also assisted over short distances by means of short waves. Its services may be impaired for considerable periods by excessive atmospheric conditions, which subject has already been referred to. The power required for communication over equal distances is enormously greater than in the case of the cable, although directional transmission and reception may yet do much in this connection. It is liable to interference from other stations by reason of the limitations of wave-bands available for distribution and the overlapping of transmission caused by want of sharp tuning and by harmonic disturbances.

Much has been done to remedy such troubles, but much remains to be done before long-distance radio communication will possess the secrecy, reliability, and economy of operation of the cable. The most severe critic of long-distance radio communication must, however, concede that for handling Press and deferred social and commercial messages over great distances and to many divergent points of the globe the radio service has unique advantages. It is capable of creating a new class of business not likely to be developed by the present somewhat costly and overburdened means of communication, and would go far to compensate for the geographical isolation which Nature has imposed upon these Islands.

DIRECTION-FINDING.

The subject of direction-finding has become of great interest and importance in shipping and aeronautical circles. There are three distinct types of direction-finders in use—the single-frame system, double-frame or Robinson system, and the Bellini-Tosi. The latter, in place of a closed loop, uses two perpendicular antenna structures, which are connected to instrumental loops, inside which an exploring-coil is revolved. All these systems depend

upon the fact that a radio wave being propagated through space may be regarded as possessing alternating electric and magnetic fields perpendicular to each other and to the direction of propagation of the wave.

In considering the theory of the loop it is convenient to regard the magnetic field of the wave, which may be resolved into a horizontal and a vertical component. Since the plane of the loop is vertical, the vertical component of the flux can never link with the coil, and may be disregarded. The action of the simple loop depends, therefore, upon the principle that the magnitude of the electromotive force induced therein by a passing electro-magnetic wave depends upon the angle between the plane of the loop and the wave-front; or, in other words, if the loop is placed so that its plane is directed towards a transmitting-station the maximum energy is picked up, and the signal developed in the detecting apparatus connected to it is a maximum; if, however, the plane of the loop lies at right angles to the direction of the station no energy is picked up and no signal is heard. At intermediate positions the energy picked up by the loop will vary as the cosine of the angle made by the direction of the transmitting-station and the plane of the coil.

The systems referred to are also similar in that the observation of the apparent direction is carried out in each case by setting some part of the rotating system—which revolves about a vertical axis—in a position in which the received electromotive force is zero, or at least a minimum.

It is fortunate for the navigator approaching a coast-line that up to distances of fifty to a hundred miles direct over sea it is found that, even under conditions of darkness, when variations in intensity and direction of electro-magnetic waves are at a maximum, no appreciable error exists. By these methods bearings may be taken with an accuracy of well under 1° of error. The direction-finding installation on a ship enables bearings to be taken on radio beacon stations on land. These beacon stations can be automatically operated, and require a minimum of skilled attention, whereas if the direction-finding station be located on land a comparatively skilled personnel is required, and the ships must await their turn when positions are required.

The advantages of a radio beacon station over a lighthouse are many. The radio beacon operates satisfactorily under all conditions of visibility or invisibility, and the range greatly exceeds that of a light. The ship's direction-finding equipment can also be used to avoid collisions at sea, and to get the correct position of a ship in distress, so long as the latter is able to send out radio signals.

Apart from these main lines of development, other systems employing beacon stations operating on short waves and using directional transmission are being successfully operated over short ranges. These systems send out a beam of radiation like an electric searchlight, giving a distinctive signal as it passes through each point of the compass. A ship, by observing on its ordinary wireless receiving apparatus the code signal being transmitted by the beacon station, can relate such a signal to a chart, giving the line of bearing corresponding to the signal which operates over that particular area. By the use of special receiving apparatus an approximation of the distance from the shore may also be determined.

The history of marine disasters in New Zealand indicates that such troubles can in the future be largely avoided by the installation of radio beacons around the coast, and of the complementary direction-finders on board ship, or *vice versa*.

SOME REMARKS UPON COALS AND THEIR CLASSIFICATION,

WITH SPECIAL REFERENCE TO THE LIGNITES OF THE SOUTH ISLAND OF NEW ZEALAND.

By Professor W. P. EVANS, M.A., Ph.D.

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A. Introductory: What Coals are, and why difficult to classify.
B. Classification—(1) According to Geologic Age; (2) according to Calorific Value; (3) according to Chemical Composition, either alone or together with other Factors.
C. Special Reference to the Lignites of New Zealand to illustrate Classification according to Composition and Physical Characteristics.

"FOR the sake of convenience it is customary to make use of our imperfect knowledge as an aid to classification." Surely this statement can apply to none more closely than to those who attempt to classify coals. But yet the picture is not wholly dark, for, if we still must use our imperfect knowledge to aid our classification, we can, without shadow of doubt, make use of our classification to help our ignorance, if not to advance our knowledge.

Hence it is that the writer of these random remarks, although firmly of the opinion that no coal-classification hitherto published is satisfactory throughout its range, and believing almost as firmly that no classification of the immediate future will be satisfactory for coals of all classes, all geologic times, and all countries, yet makes no apology for bringing the classification problem before the readers of this *Journal*, and, it may be, adding a few more pages to the large mass of literature already existing on the subject.

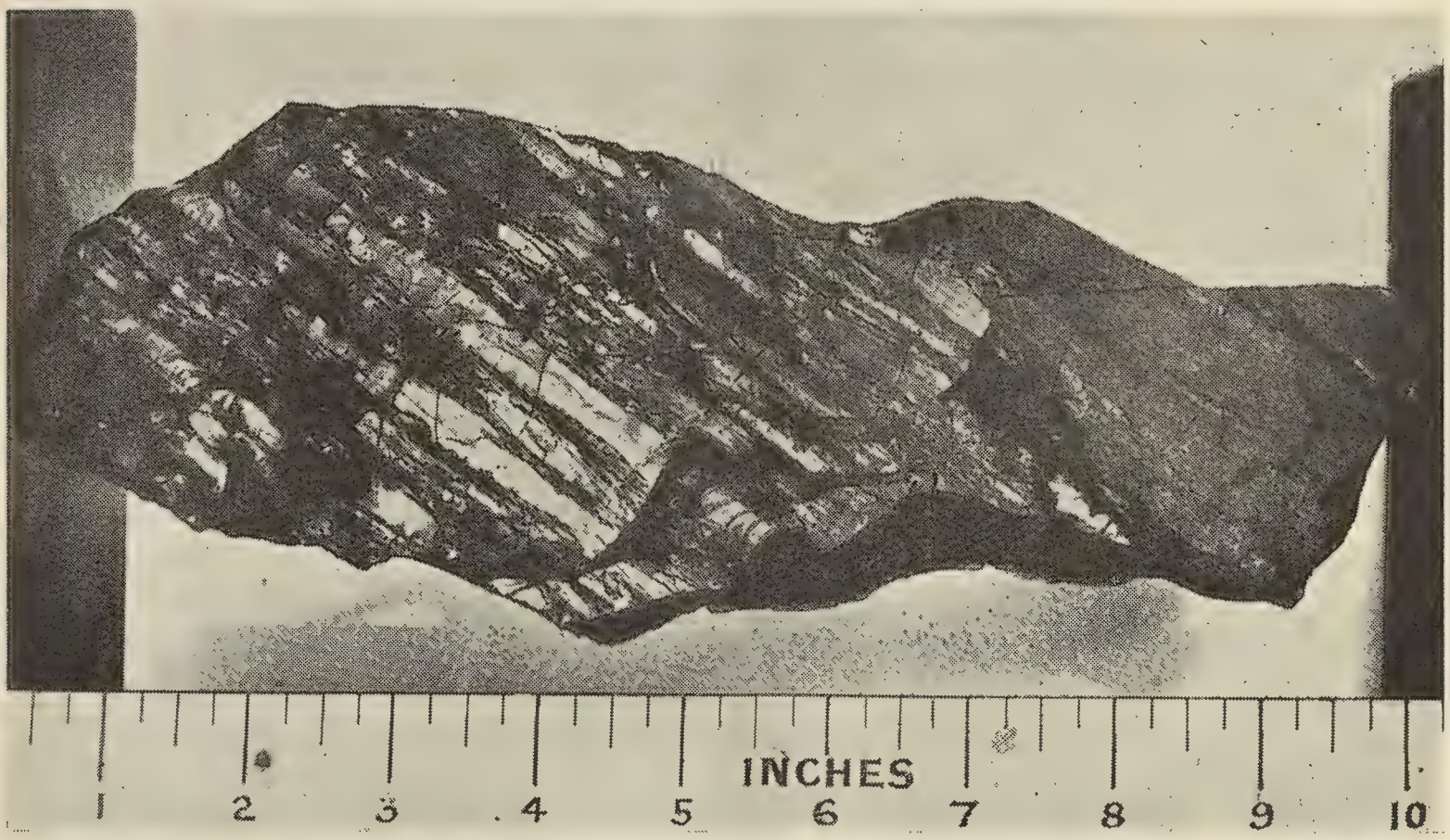
Before attempting to classify any number of objects it is as well to become acquainted, at least superficially, with the nature of the objcets to be classified. It will therefore not be out of place to begin by asking, and attempting to answer, the questions—What are coals? Why is it necessary to classify them? And, if such classification be advisable, what makes it so difficult a task?

The last two of these questions may be answered very briefly by saying that coals are so important a factor in the general industrial prosperity and wealth of nations that commerce herself demands an attempt at classification, and that any such classification is at present a matter of extreme difficulty owing to the bewildering variety in which coal is found, and to our almost entire ignorance of its constitution, as opposed to its composition, which is quite well known.

The first question will, it is hoped, be answered fairly fully in what follows; for that, as a whole, will be nothing more than an attempt to answer them all in some detail, although it may be neither convenient nor possible to treat them separately.

What are coals? In the first place, the word "coal" is used in a popular and also in a scientific sense. Popularly, coal is any dirty, black, stony material which will burn with sufficient energy to run a steam-engine

or grill a chop. Scientifically, however, it has a somewhat more restricted meaning. A lump of black Trinidad asphalt will, if properly used, make an excellent fire, but it is not a coal. A piece of oil-shale from Orepuki may, with a little coaxing, be made to boil an egg, but it is not a coal. Coal to the scientist differs from both asphalt and oil-shale not only in chemical composition but also in the accident of its birth. To him a coal must at least appear to be "a compact mass of mummified plants," and must be fairly free from all other kinds of matter. To him it is also a rock, a common stratified rock like a sandstone or a roofing-slate. But it is not all rock of one kind, for, just as there are many kinds of sandstone, or of slate, differing among themselves in colour and texture and specific gravity and chemical composition, so there are many kinds of coal-rock, differing among themselves in colour and texture and chemical composition—and, alas! in usefulness also.



Conchoidal lignite (N.Z.), showing distinctly banded structure generally characteristic of bituminous coal. The specimen had been exposed to the atmosphere of the furnace-room for five years before it was photographed, and is only slightly weathered, although it contained over 20 per cent. of water.

If coal be a mere rock, then how comes it to be also a mass of mummified plants? To answer that question one must imagine oneself living just a few millions of years ago, and further imagine oneself living on from then till now. The world of those far-off days was not our world. The distribution of land and sea was not the same, the animals were strangely different, the plants were unlike ours in outward form. In structure also these ancient plants differed considerably from those of the present day; but the individual cells of which they were built up, the elements, as one may call them, of the plant-bodies, were then as now. "Cells of nearly every type from the coal-measure period of Europe can be indentically matched with those of to-day. In the way the walls thickened, in the shape of the wood, strengthening of epidermal cells, in the form of the various tissues adapted to specific purposes, there is a unity of organization which it is reasonable to suppose depended on the fundamental qualities

inherent in plant-life."* These ancient plants grew luxuriantly over vast tracts of land. Sometimes they were upland plants; but those whose remnants were afterwards to furnish the greater portion of our coal appear to have been growing with partly submerged roots in brackish water, for, though their roots are those of water-plants, their leaves show that they had to conserve water to the utmost. With them, as with plants growing in similar positions to-day, it was a case of "water, water everywhere, but not a drop to drink." The droppings of these plants in the shape of broken stems, twigs, leaves, cones, spores, &c., accumulating through long periods of time, gradually formed the enormous deposits of vegetable debris which, after undergoing many changes due to the combined action of bacteria, enormous pressure, and in some cases, perhaps, slight elevation of temperature, were destined to form the coalfields of to-day. Most of these gigantic debris-fields were laid down under water, some, no doubt, on the actual sites of the parent forests, but many of them at a distance from the plants which furnished them, being carried by rivers and flood-waters until at last they settled down for their age-long rest. Subsidence of the land submerged them farther and farther, and a covering of muds and sands and gravels, very gradually produced, but often ultimately measuring many thousands of feet in thickness, protected them from rapid aerial decay, and at the same time afforded the slight warmth and enormous pressure which were necessary for their development from loose vegetal debris into compact coal.

Such are the very imperfect outlines of the general physical conditions under which we believe the series of sedimentary rocks called coals were laid down. It must, however, be noted that in some few cases there is very good evidence to show that animal matter also played its part in the formation of the original debris-field.

Some coals carry their origin on their faces, being "obviously made up of a number of flattened and compressed branches or leaves of which the original tissues have been thoroughly carbonized"; while others are very largely composed of the long parallel veined leaves of coal-measure plants. Many coals, however, are more reticent as to their past, but even in their case the microscope reveals crushed spores and fragments of vegetable tissues where the unaided eye sees not the slightest trace of plant-remains.

Coal, then, is derived from vegetal matter. In fact, so definite is the evidence that it has resulted from the alteration of such matter, in some form and by some means, that "a theory of origin based on any other premise may be dismissed without consideration."

Yet, though all workers upon the subject are agreed as to the vegetable origin of coal, and most of them are gradually becoming more or less united as to the methods of accumulation of the original vegetable debris into the huge masses needed to give rise to our coal-seams, there is still, after more than fifteen hundred years of controversy, great divergence of opinion as to "the processes by which the vegetation has been brought into the various forms in which it is now found."

It is, however, not necessary here to discuss the various hypotheses which have been advanced to explain these far-reaching changes, since, for the purposes of classification—and it is with classification that this article proposes chiefly to deal—the present state of the coals considered is of far greater importance than the paths by which that state was reached. The

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* MARIE C. STOPES, *Ancient Plants*, 1910 ed.

nature of the original vegetal debris can be determined by the skilled palaeobotanist only; the intermediate age-long processes of coalification are at present, and from their very nature must remain, matters for conjecture only; but the actual present condition in which the various coals are mined and used may be studied at leisure by engineer, botanist, geologist, and chemist with equal advantage, and, it must be frankly admitted, with equally disappointing results. But, because the processes of coalification are, or would be, of very great use to the classifier if he were certain of them, and also because, despite differences of opinion upon minor points, most workers on coal are practically agreed as to the main steps in the path of coalification, it will not be out of place to summarize them here.

The numerous changes taking place between the original stage of vegetal debris and the present stage of coal in great variety are usually treated as belonging to two time-groups—first the biochemical, and second the dynamo-chemical.

I. BIOCHEMICAL CHANGES.

(*a.*) The vegetal debris, covered with water, or, at least, thoroughly saturated and partly coated with mud, is subjected to the action of putrefactive organisms*; marsh-gas and various other gases are evolved, and the settling mass gradually attains the consistency of a vegetable paste, still carrying countless myriads of putrefactive bacteria.

(*b.*) By subsidence of the land the slowly putrefying mass is still farther submerged and still more heavily covered with muds and silts. The decreasing supply of oxygen gradually renders a large proportion of the organisms present inactive, and at last they die. Many, however, less dependent upon oxygen for their life, continue to decarbonize and dehydrogenize the settling mass.

(*c.*) The mass still sinking, owing partly to its own shrinkage and partly to land-subsidence, at last becomes quiescent, no further bacterial action

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* According to Renault, the agents most active in transforming the vegetable debris into a compact peaty mass are saprophytic fungi and bacterial ferments. As the former are only active in air, while the latter are anaerobic, the activity of either agent is conditioned by variation in the water-level of the mass. Renault and also many others consider that the resulting dense-black peaty substance acts as a cement which binds the more resistant parts of the plants into a compact whole. The subsequent change of this peat-bound mass into coal is then attributed—*i.e.*, by those who adhere to the peat-to-anthracite theory—to geological causes, chemical and physical processes similar to those which have converted ordinary sediments into rock.

In connection with the fermentation stage in the development of coal from peat it may be mentioned that Renault claimed actually to have observed (and published photo-micrographs of) petrified micrococci in some of the coals he examined. Although such fossil organisms have been accepted, and even amplified, by some workers, there are many reasons why they should still be looked upon as doubtful.

It will at once be seen that Renault's coalification hypothesis is actually the bioplus dynamo-chemical hypothesis outlined above. Such an hypothesis, it must be remembered, by no means implies adherence to the peat-to-anthracite theory. It is, however, becoming more and more generally recognized that coal *may be formed from peat*, provided the topographical conditions are favourable, firstly to the bacterial fermentation, and afterwards to the completion of coalification by pressure.

That such changes of level and general conditions as are herein implied are so extremely unlikely to have occurred in *all* the large number of places where coal is now found is one of the reasons why the peat-to-anthracite theory, in its fullness, is considered by very many workers on coals to be incapable of furnishing a satisfactory explanation of the formation of coals in general.

The statement of which the above is a very short summary occurs in many portions of this author's writings on coal (*v.i.a. Bulls. Soc. Hist. Nat. Autun*, 1892–94; and *Bulls. Soc. Indus. Miner.*, 1899–1900—especially ser. 3, xiii, 865).

being possible. The organisms still active now die, and add their nitrogen to that of the original vegetation.

II. DYNAMO-CHEMICAL CHANGES.

(*a.*) The gradual deposition of superincumbent strata imposes upon the coal-to-be an ever-increasing pressure, while with increasing depth the natural temperature also increases. The increase in temperature is slight only, but one must remember that very small increases in temperature have, in general, a most marked influence upon the rate at which chemical action proceeds. The increase of pressure is, in general, enormous, and exercises a profound influence not only upon the rate, but probably, in some cases, upon the actual course of the reactions involved. Further, it is to be remembered in this connection that Nature knows no eight-hours day; she works both night and day, and works for ever. So it comes about that changes produced by pressures so great as to be beyond our power to grasp, operating through a comparatively short period of time, are equalled, and in some cases even surpassed, by less stupendous pressures working through almost countless years.

It is to the influence of these earth-pressures, accompanied by the natural slight increase of temperature mentioned above, that the gradual development from micro-infested vegetable paste to coals of various characters is usually assigned.

(*b.*) Shrinkage of the earth-crust induces folding to relieve the shrinkage strains. During the folding strain the weakest strata go to the wall, or, at least, have to accommodate themselves to the spaces left for them by stronger and more "competent" strata, and so many coal strata—luckily for us if not for them—are squeezed out of all knowledge and further changed both physically and chemically.

It is to this active folding pressure that, so far as we can judge, we owe many of the deposits of most highly dehydrogenized coal.

It will be remembered that the changes just briefly outlined were spoken of as belonging to two time-groups. Such a division in time must not, however, be taken too strictly, for, although it is almost universally admitted that biochemical processes similar to those described above have been responsible for the early stages of alteration of the plant debris as it changed to coal, and very generally held that the subsequent hardening and deoxygenation are attributable to dynamo-chemical agencies, yet there is no ground for supposing that the two series of changes* did not partially

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* The two-stage hypothesis as outlined briefly above needs, perhaps, some qualification. It is indeed true that the first stage, the biochemical, may be looked upon as universally accepted. Such a statement would, however, be unjustified as regards the second. or dynamo-chemical, stage. Despite the fact that it is often referred to as if it were the only second-stage hypothesis in the field, this is by no means the case. Among the many factors which have been introduced at one time or another to replace or aid the dynamo-chemical factor may be mentioned the following:—

(1.) Differences in the kinds of vegetation forming the original debris-fields.
(2.) The length of time the debris remained unburied.
(3.) The depth of burial.
(4.) The action of heat, either from compression or from igneous intrusion.
(5.) The escape of volatile constituents through fissures in the surrounding rocks, &c.

No. 1 has, the writer thinks, been sufficiently dealt with. All vegetation is alike in its ultimate composition.

No. 2 may be dismissed at once as untenable. Long exposure *before* burial means complete decay, not an arrested decay such as must have taken place in the formation

overlap. We know nothing of the working ability of the organisms of those bygone ages, are completely ignorant of the pressures which they could and could not endure, and so can only make use of our observations upon similar organisms of our own day. In any case, it is quite possible that pressure was already beginning its work upon the changing mass before the putrefying bacterial stage was completed.

It may be well at this stage to repeat in tabular and somewhat amplified form the conditions of deposition and subsequent coalification already mentioned :—

I. Vegetable debris accumulates—
   (*a.*) Almost free from animal matter.
   (*b.*) Accompanied by a considerable quantity of animal matter.

II. The accumulated debris is exposed to atmospheric influences.

III. The debris, partly shielded from the atmosphere, suffers partial putrefaction.

IV. The putrefaction is arrested, and pressure gradually completes the coalification.

V. During, or after, or both during and after, the main-pressure period (IV) the mass is subjected to folding.

A very brief study of this scheme of derivation will suffice to give an insight into some of the many difficulties that have hitherto baffled all attempts at strictly scientific classification of the resultant coals. If we are correct, or even reasonably correct, in our surmises as to the origin of coals, then their present condition is dependent upon at least five factors, each of which is capable of independent variation. The result, therefore—in other words, the coal with which we have to deal—may show itself in an almost endless variety of form.

Not all coals come from the same kinds of plants ; not all from the same parts of those plants ; the latter difference between plant-parts being much more important than the difference between plant-kinds. Some debris-fields were exposed to atmospheric influences for a longer time than others ; some, indeed, were buried as they formed. Some were almost completely changed in nature by bacterial action long before they were covered by their mineral bedding, while others were covered almost from their birth. In some cases the aging coals were subjected to earth-pressures for the comparatively brief period of a few hundreds of thousands of years ; in others the pressures were maintained through ages "measureless to man." Some coals were allowed to rest quietly under the superincumbent rocks, while others were twisted and torn during nature's labour. Surely, then, we have a right to expect that there shall be "all sorts and conditions" of coal.

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of coal. Long exposure to atmospheric influences without much decay is sometimes explained by assuming that the air in the far-off days of Palaeozoic depositions was extremely low in oxygen. Even were this sufficient to secure immunity from attack in a moist atmosphere (and it is not), it is by no means in accord with the evidence of the fossil fauna of the period. At any rate, the same scarcity of oxygen can certainly not be adduced in regard to the formation of the recent coals of similar type.

No. 3 is but another name for difference of earth-pressure.

No. 4 can be looked upon as helpful only in certain minor cases, such as the local formation of natural cokes. All experimental work goes to contradict the hypothesis that the coal-forming masses were, at any time, subjected to any great rise of temperature.

No. 5 has, no doubt, helped in the devolatilization, but surely it is nothing else than a part of the general dynamic hypothesis.

The coals are rocks. Rocks are considered as being made up of a number of constituent minerals, and where these minerals can be identified, and their relative frequency of occurrence measured, classification of the rocks becomes, if not easy, at least feasible. Why, then, it may be asked, is the method not used in the case of those rocks which are coals? It is used as far as possible, but it is very rarely available. There are cases in which the mineralogist finds that his rock shows no separate mineral parts, but is, as far as appearance goes, all one substance; and other more baffling cases in which the minerals are partly interfused, or even masquerading in the forms which he considers belong rightly to other minerals; and then his thinking-cap has to be put on before he can say that the rock with which he is dealing belongs to this class or to that. With the coal-rocks, unfortunately, the limiting cases just referred to are the rule instead of the expcetion. The minerals—if one may be allowed to use the term—composing them have not the definite form and character that belong to true minerals such as quartz, and micas, and olivine, and augite. They are always indistinct in outline, and very rarely free from interfusion with their neighbours, so that even to the trained observer their mineralogical meaning is often meaningless.

One more difficulty may be mentioned here, although it may be necessary to refer to it again at some length. In the case of most rocks, even when their constituent minerals cannot be clearly distinguished or defined, a complete chemical analysis is of very considerable use: sometimes, indeed, it is sufficient to enable us to put the rock in its place. With coal-rocks, however, we are dealing with an organic mass, not an inorganic one, and organic substances may possess very different characters while still retaining the same chemical composition. Analyses alone, therefore, cannot be considered as a sufficient basis for classification of coals.

There is yet another side to the question of coal-classification. Coals were not made simply that they might provide the scientist with one more plaything. They are of real use in the world, and are meant to be burned in order that their stored-up energy may make men rich; and from this point of view that coal is the best which, in burning, gives out most energy. Any classification of coals, therefore, if it is to be of use to industry as well as to pure science, must take into account the calorific values of the coals classified. That is to say, any classification which has hopes of being really useful must bring into prominence—(1) the *physical characteristics* of the coals, (2) the *chemical characteristics* of the coals, (3) the *calorific values* of the coals. These three points are essential; but if in addition it can show how these are—as they certainly must be—dependent upon the origin and geologic development of the coals, so much the better will the classification be.

Coal is found in nearly all countries and in nearly all geological systems from the Devonian up to the most recent, though some countries have much larger stocks of coal than others, and some systems, notably the Carboniferous and the Tertiary, carry the greater portion of high- and low-grade coals respectively. Despite this very wide distribution, both geographical and geological, the coals of one country are strangely like those of another country, and those of one geologic time may not differ appreciably from those of another time. On the other hand, coals from the same country and belonging apparently to the same geological horizon may differ as much almost as the proverbial chalk and cheese. We are therefore forced to the conclusion that "very varied prime materials

may give rise to one and the same kind of coal; and, inversely, the same original substance may, by variation in the influences to which it has been subjected, give rise to widely different classes of final product."* This is, of course, nothing but a definite statement of the conclusion already hinted at in connection with the supposed history of the coals. The second portion of the statement, as given above in Robertson's words, needs no further comment; it is self-evident, if we once allow the fundamental hypothesis; but the first part may be worth more detailed examination.

Coals, we say, are derived from the debris of vegetation of long ago. In those far-off times, just as at the present day, plants were of many types; and, expecting perhaps to find differences in composition between the coals known to be formed from plants belonging not only to different families but also to different classes of the vegetable kingdom, competent analysts have, at times, analysed such coals. The results have always been disappointingly uniform, and doubtless the reason for that uniformity is the uniformity existing in the composition of the fundamental tissues of all plants through all times. "This fundamental fact—viz., that all vascular plants share the same chief types of tissue cells—is the explanation of the gross similarity between coals of very different geological ages: for instance, Cretaceous or Tertiary coals, made from the comparatively recent dicotyledonous flora, may be substantially identical in their response to the ordinary chemical tests with coals of the Palaeozoic age, though the species of plants forming the two coals are all entirely different."†

Taking it for granted, then, that coals are but the metamorphosed remains of an ancient flora, and taking also for granted that the tissue cells of that flora were practically coincident in composition with those of our present-day flora, we may form a fairly good idea of what to expect in the coals we are about to try to classify. That is true—quite true—so far as their chemical composition is concerned, but that is about all that can be said. Our knowledge of the celluloses (for they are a group rather than a chemical individual), of the complex ligno-celluloses, the pecto-, muco-, adipo-, and cuto-celluloses, and of the various pseudo-celluloses, is, thanks to the labours of many chemists, rapidly becoming very definite. Our acquaintance with the principal specialized productions of plants, such as terpenes, resins, and gums, is also, though very imperfect as yet, still ample to allow us to trace the remains of their ancient prototypes—or, more strictly, to trace such of them as have been sufficiently resistant to the far-reaching changes previously considered. Our knowledge of those changes themselves, however, and of the possible paths along which such changes may have been made, is really non-existent. Here then, once more, mere chemical analysis fails us. It is true that very much has been written on the subject of the various constituents derived by various treatments from coals of various kinds, but much of what has been written fails to carry conviction, and one feels inclined to use the words of Marie Stopes and declare that here also "a healthy scepticism is better than an illuminating imagination."

Using the term "wood" in its more exact meaning—*i.e.*, as embracing all the "lignified vascular tissue of the plant, whether that lignified tissue occurs in large masses compacted together as in timber, or in small strands

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* J. B. ROBERTSON, *Chemistry of Coal*, p. 14. (Gurney and Jackson, London, 1919.)

† MARIE C. STOPES and R. V. WHEELER, *Monograph on the Constitution of Coal*, 1918, p. 23.

as in the vascular systems of leaves and twigs"—it may be said that coal is derived from wood.

Average wood-fibre, freed from soluble matter and foreign bodies, contains approximately—Carbon, 48·5 per cent.; hydrogen, 6·2 per cent.; oxygen, 54·3 per cent.; and has apparently the same composition whatever be the nature of the plant from which it is taken. In addition to these elements, however, the fibre contains small quantities of nitrogen, phosphorus, sulphur, &c., of which the first two must be looked upon as absolutely essential.

Why, then, do coals, which are derived from wood-tissue, differ so markedly in composition from the parent substances and between themselves? That the differences here referred to are marked is clearly shown by the following table, which gives the *average* composition of wood, peat, and the three main varieties of coal:—

Average Percentage Composition of Fuels.

——	Carbon.	Hydrogen.	Nitrogen.	Oxygen.
Wood	49·65	6·23	0·92	43·20
Peat	55·44	6·28	1·72	35·56
Lignite	72·72	5·26	1·31	20·71
Bituminous coal	84·24	5·55	1·52	8·69
Anthracite	93·50	2·81	0·97	2·72

The table may be given another form by calculating the amounts of other elements proportional to 100 parts of carbon. If nitrogen be omitted as unimportant for the present, it then appears as follows:—

——	Carbon.	Hydrogen.	Oxygen.
Wood	100	12·5	87·0
Peat	100	11·3	64·1
Lignite	100	7·3	29·0
Bituminous coal	100	6·6	10·3
Anthracite	100	3·0	2·9

An examination of the table in this second form at once reveals two important facts. The first is that there is a steady decrease in hydrogen and oxygen as we pass from wood through the various fuels. The second is that the *proportional* decrease in oxygen is greater than the decrease in hydrogen. In pure celluloses these two elements exist exactly in the proportions required for water—viz., 1 : 8. In average wood the hydrogen is somewhat in excess of that ratio, and the ratio steadily increases until at last, in the case of average anthracite, it is almost 1 : 1.

Here, then, is the analytical basis for the assumption of progressive dehydrogenation and deoxygenation referred to as accompanying both the bio- and dynamo-chemical portions of the coalification process. Exactly how this elimination of hydrogen and oxygen took place we cannot deter-

mine—it is simply a matter for hypothesis. The elimination can, it is true, be imitated, or effected, in our chemical laboratories. But they are not equipped like Nature's laboratories: our methods are crude compared to hers; and, most important difference of all, our poor efforts must be concluded within the small span of years allotted to man, while she can work for ages. Hence the worker of our day must be content with the fact that by some means or other there has been a steady elimination of hydrogen and of oxygen from the original vegetable matter during its voyage down the rivers of time.

It is on this gradual elimination, or, rather, on the proportion in which he finds the carbon and hydrogen and oxygen actually existing in the coals at the present day, that the classifier, who works from the basis of chemical data, must chiefly rely.

METHODS OF CLASSIFICATION.

There are many ways of classifying coals. They have been classified according to their physical properties, and many of the purely local names applied to special varieties are based upon such properties—for instance, "peacock" coal, "stone" coal, "brown" coal, "splint" coal, "cubical" coal, &c. They have been classified according to the nature of the flame given by them when freely burning—as "long-flame," "short-flame," &c. They might be classified according to age—that is, according to the place they occupy in the geologic time-chart. They may be classified on the basis of their chemical composition. A sufficiently skilled palaeobotanist might classify them from a study of their fossilized plant-tissues. The man of commerce must have them classified according to their heating-power. They actually have been classified according to the percentage of water carried by them under normal conditions, and that with far more satisfactory results than would, at first thought, be deemed possible.

So many different methods of classification have, in fact, been proposed at one time or another that merely to enumerate them would be as wearisome as useless. The writer therefore proposes to deal, in the remainder of this article, with those systems only which are based upon (1) geologic age, (2) calorific value, (3) chemical composition; dealing first with coals in general, so far as is necessary to make clear the methods involved, and then, in conclusion, with certain of the lignites of the Dominion of New Zealand.

I. *Classification according to Geologic Age.*

When one considers the nature of the working hypothesis generally adopted in order to explain the formation of coal, it would seem that a classification based upon age, as entered in Nature's notebook, must necessarily be a good one, if not actually the best that could be made. So, indeed, it would be if all original debris-fields had been amassed under exactly similar conditions; if all such fields had been subjected to putrefactive agencies for the same length of time; if all the partly decayed materials had been covered by equal masses of overlying rock; if Nature lazily left everything just where she first put it down; and if geologists were always correct in their readings of the time-chart provided for them.

These conditions are, however, by no means fulfilled. The original debris-fields were not all alike: the times during which they were exposed to bacterial attack, the masses by which they were subsequently covered, differed greatly. Nature does not leave things alone, but, on the contrary,

often mixes them up in most disconcerting fashion; and, finally, geologists, like chemists and a few other well-meaning people, do sometimes make mistakes. So far is this the case that, after careful examination, classification—*i.e.*, general classification, based upon age alone—must be looked upon as worse than useless. A few specific instances will make this somewhat sweeping statement perfectly clear.

It is a matter of common knowledge that there are soft coals, and harder coals, and very hard coals; that there are poor coals, and better coals, and very excellent coals; coals that do their duty in burning and heating as if it were a pleasure, and coals which have to be bribed to anything at all but sulk. Broadly speaking, and somewhat inaccurately also, the older a coal is, up to the age of maturity, the better it is for general use; the very young coals have, as a rule, not attained their full strength, while the oldest of all have already lost some of that "go" they formerly possessed. These coals may for the present, so as not to anticipate further than necessary the technical terminology which must be adopted later, be distinguished as "low-grade," "medium-grade," and "high-grade" respectively.

The best coals known in Europe are coals of ripe old age. The younger coals of Europe are distinctly of low grade; and the younger they are, the poorer. There are exceptions to the rule, but they need not be considered at present. These high-grade coals belong to the ancient Carboniferous system: many of the low-grade coals belong to the comparatively recent Tertiary strata; some of them are of Cretaceous age.

Turning now to the coals of this Dominion of New Zealand, where we have coals as good as any, it is found that the best coals are at least as young as most of the very low-grade coals of Europe (no doubt, another example of the precociousness of colonial youth); and, more puzzling still, low-grade and high-grade coals, instead of being widely different in age, march hand-in-hand as contemporaries. Evidently an age-basis classification suited to European conditions would be hopelessly misleading in New Zealand. It is, moreover, by no means necessary to travel half round the world in order to obtain evidence against the age-basis system. Within the boundaries of a single country (certainly a large one, viz., the United States of America), but also within the compass of a single State, there exist coals of nearly all classes from low-, through medium-, to highest-grade, which are undoubtedly of the same age. Different experiences—differing hardships, if you like—have made one old and another middle-aged, while yet a third retains its youthful character. Those who first attempted to classify these coals did so by age, and actually called some of the medium- to high-grade coals "low-grade," because, from their point of view, they should have been of little value. "The geologists who first studied the coalfields of the Rocky Mountain region, finding that the coals were contained in rocks younger than the Carboniferous, classed as lignites all of the post-Palaeozoic coals. The same classification, based on stratigraphic position rather than character of the coal, has been carried to Alaska, and many coals"* shown subsequently to be of comparatively high-grade were classed as low-grade. Even coals of the hardest type have been told that they must be considered soft because they were caught in the grounds allotted to soft coals.

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* A. J. COLLIER, The Coal Resources of the Yukon, Alaska, *U.S. Geol. Surv. Bull. No. 218*, p. 52, 1903. See also further examples in *Reports of the U.S. Geol. Survey.*

These few typical instances, which might be multiplied almost indefinitely, must suffice to bear out the statement above made with reference to any comprehensive classification based upon age alone.

II. *Classification according to Calorific Value.*

Classification according to calorific value is definite, and serves well the purposes of commerce. Unless extreme accuracy is necessary, it is also a comparatively easy form of classification to make, requiring only careful sampling and approximately correct* determinations by means of the laboratory calorimeter; the rest is simply a matter of tabular arrangement. Strictly speaking, it considers that coal the best of the series which has the highest calorific value. This is, from the standpoint of industry, very generally the case, though not always so. For instance, for some technical purposes it is of greater importance to have a smokeless fuel than one with the maximum calorific value; and in other cases a long flame, even bordering on smokiness, is to be desired above all things. Thus, though the calorimetric basis gives an extremely useful and fairly accurate classification, it needs supplementing by other data, physical and chemical. This only further illustrates the statement previously made that any really good classification must take into account more factors than one. The calorimeter determination, in itself, presents no serious difficulty, and can be made, if necessary, with more accuracy* than the case usually demands. If, however, extreme accuracy is necessary, then an ultimate analysis of the coal must also be made before the necessary corrections can be applied to the heating-value as ordinarily determined. This form of analysis needs more skill than the calorimeter determination, and is usually considered a thing to be avoided in the ordinary process of coal-classification. It would seem, however, that such analysis is really essential to the formation of any strictly scientific classification; and to the worker in a properly equipped laboratory it presents no serious difficulty.

Summing up the position, it may be said that the calorific value alone is capable of furnishing a technical classification, and that, in connection with the necessary physical and chemical data, it forms the real basis of most of the classifications in use; for, although these may claim to be constructed from other data, the calorific values of the coals included are nearly always appealed to for confirmation of the reasonableness of the method employed.

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* To those not well acquainted with the use of the calorimeter these two statements may appear to be more or less in opposition to one another. In explanation it may be said that though the actual quantity of heat evolved in the calorimeter can be determined with more than the required accuracy—it is simply a matter of good apparatus and a certain amount of care—corrections are needed before the effective heating-power of the coal is arrived at. For ordinary purposes these corrections are easily made without the somewhat lengthy process of combustion analysis, but in all cases where the greatest accuracy possible is desired such an analysis *must* be made, at least in part, since further corrections involving a knowledge of the percentages of nitrogen, sulphur, and oxygen become necessary. It will therefore be understood that the calorimeter values given in ordinary classifications are *approximate* values only. The approximations are, however, so close to the true values that in the majority of cases any attempts to correct them further are simply a waste of time, other errors involved in the methods of working being far more serious.

(To be continued.)

WALPOLE ISLAND PHOSPHATE DEPOSITS.

By A. M. WRIGHT, A.I.C., F.C.S.

WALPOLE ISLAND is situated in about latitude 22½° S., longitude 168½° E.; it is a dependency of New Caledonia, and is thus under French administration. It was discovered in November, 1794, by Captain Butler in the ship "Walpole"; in 1876 it was approached by Captain Chambeyron, of the French ship-of-war "Le Curieux."

In December, 1923, the island was visited by the writer on behalf of the New Zealand Refrigerating Company (Limited), when an opportunity was taken to collect specimens for the Canterbury Museum and the University College.

For the naturalist Walpole Island is practically virgin ground, and to the geologist, zoologist, and botanist who first systematically examines it much material of scientific value will be available.

Walpole Island is about two and a quarter miles in length, and varies considerably in width; it rises to about 230 ft. above sea-level, and from the sea presents the appearance of a narrow table; the shape of the coast-line, which, in places, is a low coral reef, is roughly that of a kidney. In general the coast is of vertical walls rising to a height of 230 ft.; it is formed of fossil coral, with a surface area of about 300 acres, in the cavities of which a considerable quantity of phosphate is contained. The island is leased from the French Government to the Austral Guano Company, a firm which controls the output from a number of phosphate- and guano-containing islands around New Caledonia.

Walpole Island stands by itself, with no fringing reef, but at the foot of the cliffs a flat reef extends as a platform round a considerable part of the island; below this again another reef, partly covered at high tide, appears in places. Upon the surface of this second reef newly formed and growing coral is found.

The island is accessible from below at one spot only, near the south end, where there is a break in the cliffs. Here a landing-stage has been erected, and moorings are laid in the most sheltered position available.

As far as can be ascertained, there is no external evidence of volcanic action upon the island, except in so far as the presence of iron and aluminium compounds in the phosphate furnishes a clue to vulcanism.

The surface of the island is covered with stunted trees mixed with a dense undergrowth of various species of plant-life. Apart from the live-stock kept for food purposes—goats, pigs, and cattle—and some mules used to draw the trucks, the animals seen were not plentiful. Of the birds, the bo'sun, gannet, and native pigeon appear to be the most common. Three varieties of butterflies, a scale insect, cockroaches, and centipedes were seen. Numerous lizards were also found. Flying-foxes, water-snakes, and a few snipe were among the animals visible.

The commercial importance of Walpole Island lies in the quality and quantity of the phosphatic guano found there. This deposit is, except for the resources available at Clarendon, in Otago, the nearest source from

which New Zealand can draw its supplies of phosphate. The phosphatic content of the guano is present in a form which is readily available as plant-food, being soluble in soil-solutions. Thus agriculturally the Walpole Island material is probably the most valuable of the untreated phosphatic fertilizers imported into New Zealand. It has been found that, in general, the principal requirement of New Zealand soils is phosphatic, for experiment and soil survey have demonstrated the fact that there is a lack of available phosphate in most of the soils of this country.

Upon Walpole Island the phosphatic guano is found in the depressions amongst the coral rock on the top of the island. These depressions vary in depth from a few inches to 20 ft., but probably the average depth of the cavities in which the guano is found is about 30 in.

The material as dug out is a loose, earthy, or "alluvial" phosphate, chocolate in colour, and practically inodorous except for an emanation similar to that from a newly ploughed field. It is removed to the drying-places, which are merely cleared spaces upon which the material is thinly spread out in order that the moisture may evaporate in the hot sun and tropical breezes. From the drying-grounds the guano is taken to the mill, where it is screened and the larger particles are crushed. During the wet season the guano is dried in steam-heated vacuum driers. The fine material is then bagged and ready for shipment. The method of transport from the landing-stage is by means of chutes, down which the bags are sent to lighters, which are worked between the shore and the ship, a distance of about 220 yards.

The origin of the phosphatic deposits on the Pacific islands has been the subject of various theories, but there is little doubt that they are primarily due to bird-droppings. The well-known habit of birds of congregating in rookeries during the night and at certain seasons of the year tends to being into a common receptacle the material which they have gathered and which is deposited in their excrement and in the decay of their bodies. In former times the magnitude of the rookeries was probably greater than now. It is well known that birds, seals, and similar animals select for their rookeries locations which give them security from predaceous animals and an undisturbed breeding-place for their young; many of the coral islands of the Pacific are such locations, and there is no doubt that Walpole Island was the former habitat for very long periods of countless millions of birds.

The droppings of birds consist chiefly of the phosphates of lime and of ammonia, the carbonates of lime and magnesia, sulphate of lime, and organic matter. Various changes take place under the conditions existing in the tropical islands. The volatile constituents, such as the ammonia, are given off to the atmosphere through the heat of the sun; the rain and the sea-spray leach out the soluble material, which interacts with the coral floor beneath the deposit, forming various chemical compounds, principally tricalcic phosphate; while the magnesia from the deposit converts a portion of the coral into dolomite. Some of the organic matter is acted upon by bacteria, converting it into ammonia and nitrates; the former is volatilized and the latter leached out. The carbohydrates are converted into water and carbon dioxide, which react with the coral rock. The organic phosphorus and the sulphur are ultimately converted into phosphates and sulphates of lime. It will thus be seen that the ultimate fate of the bird-deposits is their conversion into a more or less leached phosphate overlying a coral floor.

The following results have been obtained from an examination of a composite sample representing over 2,000 tons drawn from a shipment of Walpole Island guano received in New Zealand; other samples drawn from different cargoes have given similar results.

	Per Cent.
Water (hygroscopic)	11·32
Water (combined)	0·39
Organic matter	11·39
Calcium oxide	30·36
Magnesia	0·56
Iron oxide	4·15
Alumina	9·25
Carbon dioxide	2·04
Phosphoric anhydride	27·37
Sulphur trioxide	0·20
Silica	2·23
	99·26

It will be seen, when these results are recalculated, that there is an excess of phosphoric anhydride over that required to combine with the calcium available, after allowing for the carbonate and sulphate present, to form the tricalcic phosphate; this residual phosphoric anhydride is combined either with the iron or the aluminium, or with both, consequently three possible combinations are shown in the following results, as (*a*), (*b*), or (*c*).

	(*a*.)	(*b*.)	(*c*.)
Water (total)	11·71		
Organic matter	11·39		
Magnesium carbonate	1·17		
Calcium carbonate	3·24		
Calcium sulphate	0·34		
Tricalcic phosphate	52·37		
Iron phosphate	7·22	..	2·25
Aluminium phosphate	..	5·86	4·04
Iron oxide	0·34	4·15	2·96
Alumina	9·25	6·80	7·56
Silica	2·23		
	99·26		

In whatever form the combination exists, it is found that there are residual amounts of iron oxide and alumina which are uncombined. In no other phosphatic deposit on Pacific islands are free iron oxide and alumina present in appreciable quantity; and, in view of the fact that there is but little other evidence of vulcanism on the island, the problem is one of geological interest.

It must be stated, however, that from an agricultural point of view the amounts of iron and aluminium compounds are of negligible importance; many soils contain a similar proportion of iron oxide and alumina.

A number of tests have been carried out in connection with the citric-acid solubility of the Walpole Island phosphatic guano, and from these

tests the following data are found; similar results for other phosphates are shown for comparison:—

	Walpole.	Nauru.	Ephos.	Australian.
Total phosphate calculated as tricalcic	59·7	83·0	63·5	62·4
Solubility of 1 part in 100 parts of 2-per-cent. solution of citric acid for seventy-two hours, expressed as percentage of total phosphate ..	37·2	32·7	40·8	19·9
Solubility of 1 part in 5,000 parts of 0·2-per-cent. solution of citric acid for half an hour with agitation, expressed as percentage of total phosphate	76·8	72·9	89·9	26·4

The author desires to acknowledge the assistance given by Mr. H. O. Askew, M.A., in connection with the various analyses made. Acknowledgment is also made to Mr. H. B. Black, managing director of the Austral Guano Company, for facilities and courtesies extended during the visit to Walpole Island.

THE ROYALTY SYSTEM IN THE KAURI-GUM INDUSTRY.

By R. W. FIRTH, M.A., Dip. Soc. Sc.

THE problem of securing an adequate reward to the men who form the labour element in any industry is of perpetual interest to worker and economist alike. Any examination of the various systems of remuneration which have been in vogue in any occupation in the past has, then, a two-fold value. In portraying the past relations between the various sections of producers it helps to reveal one aspect of the economic development of the country, and it also sheds some light on the reason for existing conditions in the industry.

In this respect the kauri-gum industry toward the end of last century reveals several features of historical and economic interest to the student of New Zealand social conditions. In addition it presents to some extent a parallel or variant of an oft-discussed European wage-system of some decades ago—the payment of wages in kind, or, as it has been designated, the truck system. It may be of interest to learn that on the desolate scrub-covered gum lands of the far North of New Zealand there arose a variation of this method of payment which was the cause of so much denunciation in England some thirty years before.

About 1890 there were in vogue several systems by which the kauri-gum digger paid the owner or occupier of the land for the privilege of extracting the valuable resin. Payment in some form or other, though not necessarily in money, was of course essential, and was termed a "royalty." It was regarded, not as an equivalent for the gum itself, but as a payment for the right to work. The kauri-gum industry is unique in several ways, none more so than in this: that the practice has always been for the diggers to work for no employer. Each man is his own "boss," relying for his

living on the quantity of gum he obtains or chooses to obtain by his exertions. An employer of labour on the gumfields is almost an unknown quantity. The digger, then, does not receive "wages" in the general acceptance of the term, but his rate of return is conditioned to some extent by the agreement which he can make with the owner of the soil concerning the royalty. It must be mentioned that the royalty system applies only to private fields; on Crown lands the digger pays no royalty, only a license fee.

About thirty years ago the simplest form of contract on the fields was that under which the digger made either a payment of a definite sum of money or of a certain proportion of his output for the right to dig, and was not bound by any stipulations as to where he should buy his provisions or take his gum for sale. This system, involving the payment of the royalty in cash, and otherwise leaving the digger perfectly free, held the general approval. The roving gum-digger desires liberty above all things, and this form of contract was quite satisfactory to him. Unfortunately, it was the rarest form of all. There were three main types of transaction in which a gum-digger engaged: the payment of royalty; the selling of the gum he dug; and the buying of provisions and stores. Now, the situation was complicated by the fact that the owner or lessee of the land was generally a storekeeper, who both sold provisions and bought gum as part of his regular trade; and the temptation to attach to the royalty contract certain conditions regarding the sale of gum and the purchase of provisions was often too great to be resisted. In very many cases, then, the agreement was drawn up so that the digger, in addition to making a money payment for the right to extract the gum, was required also to sell his gum to the owner of the land. At times the stipulation pressed still further, and the digger had to sign an agreement by which he acknowledged himself to be only a bailee of the gum he dug, which was equivalent to an admission that the act of selling it elsewhere would amount to larceny. In addition the digger was often forced to buy all his provisions from the store of the owner of the land, or from such persons as he should direct. Thus the report of the Commission of 1898 states: "On a leased field or freehold land the owner or occupier can of course make what terms he pleases with the digger who expresses his wish to work on such property. In some cases the occupier requires either a rental per annum or a royalty on the quantity of gum extracted; but in many other cases he allows the digger to take what gum he pleases from the ground on condition that the gum is sold to the occupier and all provisions are bought at his store." In such cases it is apparent that the storekeeper was willing to forgo his royalty in the expectation of being able to recoup himself in the transactions in gum and provisions with all the diggers on the field. In any district the storekeeper, whether on Crown land or a private field, was in a dominant position. He was by circumstance, as a rule, the only man who carted over the ground, and in consequence the digger had great difficulty in getting his gum conveyed elsewhere in the event of his refusing to do business at the local store. Moreover, in some cases, where there was but one store in the district, pressure was applied to men who were digging not on lands leased or owned by the storekeeper, but on adjoining Crown lands, and they were compelled to sell their gum to him at a low price, on pain of being refused supplies of provisions even if they offered cash for them. By such methods the storekeeper greatly restricted the economic freedom of the kauri-gum digger, and complaints that he charged the latter too much for his pro-

visions and paid him too little for his gum were fairly prevalent. Thus, in the isolated and lonely districts of the far North the lack of communication, and transport, and the resultant cost of sending the gum away to some distant market, compelled the digger to accept the harsh terms of purchase.

But the precise variety of this system to which most objection was made by the diggers, and which is of most interest from a comparative point of view, was in cases where the owner or occupier of the ground did not pay for the gum he bought in money, or receive money for the stores he sold, but credited one against the other in his books and handed over the balance in cash. Indeed, this method extended so far that sometimes the balance of cash was not delivered to the digger at all, but merely carried on in the storekeeper's ledger as an amount which the digger had to his credit. Hence he found it almost impossible to secure any money whatever without taking legal proceedings, which in such remote country districts would entail great trouble and expense. This system of credit, or balancing of gum against provisions, was designated by the diggers as the "truck system."

Strictly speaking, the truck system is "the barter system introduced between employer and employed, and signifies the practice of paying wages other than in cash" (*Palgrave's Dictionary*, vol. 3, p. 586). Since there are practically no employers or wage-earners on the gumfields, the use of the term is not quite correct, but the diggers were in no state of mind to listen to text-book definitions; and, as the system here referred to presents the same essential features as that in vogue in Europe some thirty years before, the current term may be retained without involving any vital change of meaning.

It is obvious that in many cases the digger was at a considerable disadvantage through not being paid in cash. In the first place, his economic independence was considerably restricted, and his mobility as a class hindered and reduced. To a considerable extent the digger was tied to one field, and bound to the storekeeper, who, if at all unscrupulous, could keep him in that position by so adjusting his prices that the quantity of gum he produced just paid for the provisions and tools he obtained from the store. It is alleged that this was done in some cases. The storekeeper was also accused of manipulating the price of gum to suit himself, and the relative lack of bargaining-power on the part of the men gave him every inducement and opportunity. The writer was told by a reliable digger of forty years' experience that many years ago on the Mangawai field the price of gum always fell 5s. per hundredweight just before Christmas, at the identical time when all the diggers wished to sell in order to obtain the money to spend the festive season in Auckland.

Nor were the diggers always behind in sharp practice. The story is still told by old hands how one ingenious individual, knowing that white "range nuts" were twice as valuable as black "nuts," obtained a quantity of the latter and carefully shook them up with some white pipeclay from the hillside. The result was a fine-looking product, which completely deceived the storekeeper until a close examination detected the fraud—but too late.

In the stories that the diggers tell of the olden days there is much of trickery and fraud on both sides, but a large proportion of this must be attributed to the system, which so often kept the digger in ignorance of his rightful dues, and prevented him from pursuing his best economic interests. On the Northern Wairoa fields one of the digger's chief complaints was that he could not tell what he was being charged for the right to dig: in other

words, the amount he paid as real royalty was obscured by the truck system. Furthermore, he could obtain little or no redress.

The report already quoted continues: "If the digger considers that too much is being exacted from him in the way of unlimited tribute on his gum and provisions, his only remedy is to move farther on, either on to the lands of the Crown or those of some other proprietor." But of what avail was this? The digger had no definite knowledge as to the situation in other parts of the country. Most of the other private fields had the same system, and some of the Crown lands could only be worked by agreeing to the stipulations made by an adjacent storekeeper. In many instances, therefore, the inducement was not sufficient to cause the digger to reject the conditions under which he worked.

In his standard work on *The Wages Question* Professor F. A. Walker refers to the same point when discussing the more intensified form of the English system: "The fact is, the system of truck and machine rents as administered in England in the early part of the [nineteenth] century completely blindfolded the workman, and left him to grope about in search of his true interest" (p. 340).

The disadvantages and potential evils of the system have been pointed out, but it is only fair to note that, though the system may have been harsh, it was not, apart from exceptional instances, oppressive. The Kauri-gum Commission of 1893 reports: "Taking the facts of the case as they are, we have not sufficient evidence to satisfy us that the dealings between the holders of gum lands and the diggers deserve to be designated the 'truck system,' if that term is intended to convey any opprobrious sense, or that such lessees habitually take unfair advantage of their position to defraud the diggers." Despite the somewhat Gilbertian flavour of the word "habitually," the comment of the Commission is probably fair enough. Such cases of actual injustice as occurred were, on the whole, isolated instances, and cannot be said to characterize all dealings between the diggers and the owners of the fields. It was in its potential power to oppress that the danger of the system lay.

This balancing of gum against stores, and non-payment in cash, had several positive advantages. The greatest merit lay in the easy method it afforded to the storekeeper to grant credit to the gum-digger without risk to himself. The thriftless nature of the digger, and his chronic lack of wealth on arriving at a new field, generally required that he should be supplied with provisions and stores for a week or more until he had produced his first quantity of gum for sale. By the insertion of the purchase clause in the agreement the storekeeper ensured that he had a reasonable chance of receiving payment, whereas otherwise his chances were often dubious. Cases were not unknown in the North where a digger, after receiving cash for a quantity of gum, preferred to "fold his tent, like the Arabs, and as silently steal away," rather than dissipate his new-found wealth by paying his just debts. Like Maning's trader in *Old New Zealand*, no storekeeper on the fields in those days ever became rich by trading with the gum-diggers.

The so-called truck system, in addition to giving security to the storekeeper, was of value to the digger also, as it procured him credit with an ease and readiness which has not been so apparent since its abandonment. This facilitation of credit was really a matter of great importance in a community where ready money was relatively scarce. Furthermore, the digger was ensured of a ready and certain market for his gum, and was relieved of any necessity of transporting it to a distant centre in order to find a market.

In spite of these merits, however, the diggers, realizing more keenly than any one else the possibilities of oppression inherent in the system, and having before their eyes, to add weight to their fears, various examples of the injustice capable of being inflicted by it, began to press for its abolition. Great agitation took place all throughout the North, and other questions, notably the influx of Dalmatians on to the fields, also came under discussion. The feeling was probably keenest on the Northern Wairoa, and on the 22nd July, 1893, a public meeting was held at Dargaville, and Messrs. R. Hume and A. R. Ellis were appointed delegates. The latter, who is still connected with the gum industry in an official capacity, has had a long experience of the fields, and from him the writer has obtained much information regarding social conditions on the kauri-gum lands some thirty years ago. At a succeeding meeting the first and only gum-diggers' platform was laid down, and embraced, among other planks, the abolition of the truck system on the fields. The demand was made that the Truck Act of 1891, which did not apply to transactions between gum-digger and occupier of the land, should be extended to cover such contracts. The payment of royalties, the buying of stores, and the selling of gum would then be all conducted on a cash basis, and there would be no equating of gum with stores or obscuring of the amount paid as royalty. The demand was resisted for a time, but the agitation spread throughout the gum-diggings, and at length the scope of the Act was broadened to this effect.

As a result the diggers as a whole secured a greater degree of economic freedom than before. Economists know that such was the case in England when the same kind of legislation was introduced there to restrain similar practices. To quote Walker again: "Interference with the formal freedom of contract in these particulars served to enhance, in a most important degree, the substantial freedom of movement among the labouring classes" (*op. cit.*, p. 338). This freedom of movement was possible to the digger for two reasons: In the first place, he was not bound to the storekeeper as closely as before—the introduction of the "cash nexus" left him much freer; secondly, he knew exactly what he was being paid for his gum and what he was charged as royalty—facts which hitherto had often been kept from him. Moreover, he now knew accurately the state of affairs in other fields, and so was capable of following his best interest. One effect of the Act has been, however, to diminish the ease with which the digger may obtain credit in starting work on a field. The storekeeper nowadays must take more risk than formerly in having less security for any advances he may make in the shape of tools or provisions. There has thus been to some extent an adverse reaction on the primary producers; but to my mind this has been more than offset by the increased mobility afforded to them, and the removal of the graver potentialities of injustice.

The royalty system of to-day is in principle essentially the same as that of thirty years ago—it is still a payment for the right to dig. It differs, however, in that it depends entirely upon monetary transactions. Sometimes it is paid in the form of a certain sum per acre, often as a percentage of the yield, a common royalty being 10 per cent. of the total price of the gum, less freight. It is worthy of note that royalties have increased in value with the passing of the years, many of them being much beyond the power of the ordinary digger to pay. The tendency of the present day seems to be for the individual digger to restrict himself to the Crown lands, while the working of the private fields tends to be undertaken by several men working in partnership or by companies or syndicates. In this way the requisite amount of capital to pay the royalty or to initiate production is more easily obtained.

WOOL-FAT RECOVERY IN NEW ZEALAND.

By H. J. Finlay, M.Sc., Edmond Research Fellow, and Professor J. K. H. Inglis, D.Sc.

It has often been suggested that all New Zealand wool should be scoured in the Dominion, and wild statements (*c.f.* Report of Industries Committee, 1919) have been made as to the profit that would accrue to the country if this step were taken and if proper arrangements were made for the recovery of valuable products from the scouring-liquors. In the big English centres, where many large mills are situated comparatively close together, it is quite feasible to treat all the scouring-liquors at one central station, and thus not only recover marketable material but also ensure that a satisfactory effluent passes into the sewers. But in New Zealand the woollen-mills are so far apart and the wool is collected from over so large an area that the cost of transport would make it hardly practicable to scour all the wool at one centre and then distribute the clean wool as required for the mills or for export. It is obvious, therefore, that if wool-fat recovery is to be undertaken in New Zealand it is necessary, firstly, to have accurate information as to the value of the by-products for an average mill, and, secondly, to have a process which can be worked economically in small units. Hence when, through the munificence of Mr. John Edmond, the Edmond Research Fellowship was established at Otago University the work of the first Fellow (Mr. A. S. Hogg, M.Sc.) was directed towards this problem, and as a first step analyses of a series of typical wools were made, so as to show what quantities of by-products were available.

The only valuable by-product, apart from the wool-fat, is the potassium salt—potassium oleate ; and the recovery of this is a far more difficult problem than the recovery of the wool-fat. In order, however, to make the experimental data as complete as possible, full analyses of the wool-samples were made, involving determinations of moisture, fat, potassium oleate, and pure wool, the dirt being obtained by difference. The analyses were carried out as follows : A weighed sample of the wool was dried in the steam-oven and the loss of weight calculated as moisture. From this dried sample the wool-fat was extracted with ether in a Soxhlet apparatus, and its weight determined after evaporation of the ether. The remaining wool was then repeatedly washed with water, the weight of potassium oleate extracted being determined by evaporation. This treatment left pure wool and dirt, and, there being no grease, these were easily separated mechanically by shaking over a sieve. Twenty-one analyses of eleven wool-samples were made in this way by Mr. Hogg, and the average results are given below :—

	Merino, 64/60.	Half-bred, 56/60.	Crossbred, 46/48.
Moisture	13·0	12·0	14·0
Wool-fat	19·0	9·5	6·5
Potassium oleate	8·0	8·0	9·5
Pure wool	39·0	63·0	62·0
Dirt (by difference)	21·0	7·5	8·0

From these figures (which are average results and often vary considerably with the sample taken) we have calculated the amounts of wool-fat and

potassium oleate recoverable in the case of a fair-sized mill putting through 650,000 lb. of greasy wool a year. A fair average for the composition of such a total would be 300,000 lb. of merino, 150,000 lb. of half-bred, and 200,000 lb. of crossbred wools. From these quantities the amount of wool-fat would be 84,200 lb. and of oleate 53,000 lb. (equivalent to 11,000 lb. of potassium carbonate). The values of these two products fluctuate, but a good wool-fat commands about 8d. per pound in London, and the crude product brings in at least 4d. per pound if it is fairly free from acid impurity. On this basis the value of the wool-fat alone would be £1,400 or more per annum. Our experiments have shown that it is possible by suitable washing to improve the quality of the grease and so increase its value.

A possible method for obtaining the wool-fat is the extraction of the crude wool with solvents—*e.g.*, petrol—before any scouring is done at all. Such a process seems unsuitable for New Zealand conditions. The plant is elaborate, the solvents are expensive when wastage is considered, and in the case of most solvents there is a decidedly heavy fire risk.

In England a treatment of the scouring-liquors is necessary from two points of view. In the first place, a crude liquor will cause deposits in the sewers, and is therefore prohibited by law; and, in the second place, it was long ago recognized that valuable material could be recovered. The older process—the Cracking process—consisted in adding sulphuric acid to the liquors. This acid decomposed the soaps which held the grease in suspension as an emulsion, and the grease then rapidly separated. It was, however, largely contaminated with acids from the soap, &c., and had a low market value. Other processes have been tried, and in one of these—the Smith Leach process—all the material is recovered in marketable form together with pure water ready to be used again in the scouring plant. This process, however, is somewhat elaborate, and is hardly suitable for the smaller New Zealand plants, as the cost of fuel and labour would be comparatively high.

Our work was at first directed to see whether some form of centrifugal separation was possible. During scouring the largest proportion of the grease is separated from the wool in the first scouring-tank; and consequently it is necessary to take into account only the water used in this tank, and not the total water used in the scouring process or for all purposes.

A mill of the size considered would require about 2,000 gallons per day in this first tank alone, or, say, 520,000 gallons per year. This would contain about 84,200 lb. of wool-fat, or about 1·6 per cent. When one considered that cream-separators strip milk so completely that less than 0·1 per cent. of fat remains, it seems probable that this method would be applicable. As the figure for the fat (1·6 per cent.) is a very important one, but is derived from analyses of small samples, it seemed advisable to check it, if possible, by the analyses of scouring-liquors when a known quantity of wool of average composition had been scoured. This has been done, and the scouring-liquors from 3,000 lb. of wool were analysed. It was found that whereas the percentage of fat by calculation was 1·75, the actual fat recovered from the scouring-liquors by suitable solvents was 1·61 per cent.

This fundamental figure being in this way verified, we wrote to some of the chief manufacturers of centrifuges in England, and found that suitable separators can be obtained, and that the makers are prepared to supply a complete equipment for this purpose. One of the troubles, however, that arise in this method of separation is that the scouring-liquor contains con-

siderable quantities of dirt in suspension. This can be partly removed by careful sedimentation in heated settling-tanks, and it is found that by passing the partly cleared liquor through a suitable centrifuge the whole of the remaining dirt can be caught in the centrifuge, while the bulk of the wool-fat (60 per cent.) passes off at one outflow, a clean liquor containing the rest of the wool-fat passing off at another outflow. This clean liquor can then be passed through smaller and more efficient supercentrifuges which recover another 30 per cent. of the original grease. But it is doubtful whether under New Zealand conditions it would be worth while using the second centrifuge, as there is usually very little trouble in disposing of a clean effluent.

It is to be noticed that this process does not recover the potash salts, and it is very doubtful whether such recovery is a commercial proposition. But our investigations have established the fact that the partial recovery of wool-fat is a payable proposition. The labour cost would be low, and the value of the wool-fat would pay off the whole capital cost in less than two years.

THE CULTURAL HISTORY OF THE PACIFIC.*

By A. C. Haddon, M.A., D.Sc., F.R.S.

The cultural history of the Indo-Pacific area, more especially that of Oceania, has been approached from various aspects which have led to diverse conclusions, the latest of which is that which has been elaborated with great skill and erudition by Mr. Perry in his book *The Children of the Sun*. Unless otherwise indicated, the following account is a brief analysis of the thesis advocated by Mr. Perry.

Widely scattered throughout Oceania are the remains of stone buildings, consisting of stone platforms, pyramids, stone walls, occasionally also stone tombs, standing stones, stone circles, and dolmens; even stone houses may occur. These are often associated with irrigation terraces and stone statues. Many of these megalithic structures were in use at the time of the early European voyagers to the Pacific, but some of them even then were derelict. The most extensive and elaborate of these occur in Micronesia, in the Mariannes and the Carolines. Thus, in the past, the greater part of the population in Oceania erected stone buildings, carved stone images, and practised irrigation, or terraced cultivation, or both. On the whole, the civilization of Oceania has suffered a considerable decline, so that present-day communities live alongside remains beyond their capacity to construct.

From the botanical evidence it seems that the founders of Polynesian civilization came into the Pacific by way of Indonesia, for the bread-fruit, the banana, and perhaps the taro must have come thence.

Botanical and archaeological evidence agree in postulating an early period when a stream of civilization moved out into the Pacific, carrying with it the fundamentals of a relatively advanced culture, which Mr. Perry terms the Archaic Civilization. Then came a period during which the communication was cut, and the Pacific lay isolated from the west until the

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coming of the Europeans. Everything points to the conclusion that the origins of the civilizations of the Pacific must be sought in Indonesia.

The cultural history of Indonesia suggests that the first food-producing people were more highly civilized than the tribes of the present day. When the old civilizations passed away nothing replaced them, and it is only where their influence extended that cultural progress has taken place.

According to Mr. S. Percy Smith (*Hawaiki*, p. 283), the ancestors of the Polynesians were in India in 475 B.C. A migration to Java took place in 65 B.C., and bread-fruit was discovered in Indonesia in A.D. 50. This was the period of the legendary hero Maui, the son of Tangaroa (p. 153). Polynesians were living in Fiji, and the first mention is made of Samoa and of Hawaii in A.D. 450. About A.D. 650, voyages of discovery from Fiji took place, when most likely the Tahitian groups, the Marquesas, &c., were colonized (p. 175). Ui-te-rangiora made an expedition to the Antarctic, which fired Ara-tanga-nuku, three hundred years later (A.D. 950), to a similar enterprise "to see the wonders of the ocean"; he describes the frozen sea, the icebergs, the sea-lion, and the 500-ft.-long leaves of the bull-kelp. Voyages from the south to Hawaii ceased in A.D. 1325, and finally a movement about 1350 landed the great body of the Maoris in New Zealand (p. 283). As Mr. Percy Smith truly says, "Who will deny to the Polynesians the honour that is their due as skilful and daring navigators? Here we find them boldly pushing out into the great unknown ocean in their frail canoes, actuated by the same love of adventure and discovery that characterizes our own race. Long before our ancestors had learnt to venture out of sight of land, these bold sailors had explored the Antarctic Seas, and traversed the Pacific Ocean from end to end. . . . More often than not they made these adventurous voyages with the definite object of establishing new colonies in which to settle, taking with them their *Lares* and *Penates*, their domestic animals, seeds, plants, and families" (pp. 178–79).

The Melanesians have no traditions of migration into their region; they claim to have been created on the spot. Some of them now use megalithic monuments of types not now made in Polynesia. They have retained more connection with the past, but there has been loss of culture; but San Cristoval, the New Hebrides, and New Caledonia seem to stand nearer in culture to the archaic civilization than any part of Polynesia at the present day. The Polynesians, however, continually have lost certain elements of their culture while moving from place to place.

THE CHILDREN OF THE SUN.

Ample evidence exists to show that the early chiefs in Polynesia were equated to gods. A Tahitian king, by virtue of his coronation ceremony, was made into an incarnate god. There are traces of the existence in the past of a sun-cult, and the chiefs were Children of the Sun; these were characteristics of the archaic civilization. The same holds good for those parts of Melanesia and Micronesia where signs of the archaic civilization are most prominent, the Children of the Sun form the ruling class, and the same obtains in Indonesia.

The sun-god has almost universally been replaced, usually by a war-god, and there has been a corresponding change in the habits of the communities. Thus the inhabitants of the Carolines formerly had the Children of the Sun as rulers; then came invaders who broke up the former civilization, and most of the important Polynesian gods are war-gods, who often have demonstrably displaced solar gods. In Oceania there is plenty of evidence to show that the earlier people were probably peaceful. When

communities give up their peaceful habits and take to fighting on a large scale, attention is diverted from one occupation to another. In the Pacific the rise of warfare coincides with the degeneration of culture in the arts and crafts.

According to Mr. Perry, everywhere the aboriginal inhabitants of a country were peaceful food-gatherers, with little or no social organization, wandering about in family groups.

Then there arrived at various points—India, Cambodia, Polynesia, Mexico, &c.—an advanced civilization based on irrigation, located near sources of wealth of various sorts, gold, pearls, and pearl-shell being the most important, and characterized by stone-working, and other arts and crafts. Some of these early settlements were obviously only there for the purpose of mining, and no attempt was made to colonize the country. But in others settled communities and even cities sprang up, which were ruled over by divine kings, usually claiming descent from the sun.

This archaic civilization gave rise to others less advanced in the arts and crafts, but more warlike, and naturally with war-gods; but the rulers of the later communities were not divine kings. Directly to these warlike habits may be ascribed the ultimate disruption of the archaic civilization.

The Children of the Sun were looked upon as gods; they were accredited with great powers; for instance, they were supposed to control the weather, fly through the air, visit the world in the sky, and do all manner of things impossible to mortal men, and when they died they returned to the sky, whereas the commoners were relegated to the underground world.

It is reasonable to believe that the war-gods—who were once men—throughout the Indo-Pacific were actually members of the ruling group of the archaic civilization; originally they were but semi-divine. The warrior nobility at death passed to the underworld, like commoners, and the war-gods, too, are connected with the underworld.

Melanesian culture-heroes belong to the sky-world, and they, with the culture they introduced, must be relegated to the archaic civilization; but they do not receive any active cult, for the religious systems of the Melanesians are centred round ghosts of ancestors.

THE GIVERS OF LIFE.

Polynesia, with its hierarchy of gods and priests and elaborate ceremonial, stands in strong contrast to Melanesia. When the Children of the Sun disappeared, the worship of sky-deities declined; but in many cases the rites that they instituted have persisted in what are generally termed magical practices. Indeed, Mr. Perry suggests that the magical rites of any tribe are centred about certain "Givers of Life" which derive their powers from historical association with the archaic civilization.

If the later ruling class has been derived from the archaic civilization, then the archaic nobles, at least, must have formed two groups, one associated with the sky, the other with the underworld.

The archaic civilization in its earliest phase was characterized by a belief in a Mother-goddess, the ruler of the underworld, associated with agriculture and human sacrifice, the latter degenerating into cannibalism and head-hunting. The earliest food-producers in Melanesia were matrilineal, and there is evidence that throughout the Pacific mother-right has given place to father-right, and gods are now in the ascendant, with a Great Mother in the background. The transition was accompanied by other cultural changes, such as the development of warfare, the disappearance of the Children of the Sun, &c.

A dual organization, with marriage between the moieties, is characteristic of the archaic civilization. Primarily it seems to have been confined to the chiefly classes, but ultimately, according to Mr. Perry, it was extended to the whole of the community; when the solar chiefs disappeared, so did the duality of the sky and underworld, but the other side of the ruling group artificially set up a like organization which naturally was associated solely with the underworld.

What is known as totemism appears also to be associated with the archaic civilization. The essence of the system is the clan, which originally was matrilineal, for the clan plays an important part in the political life of the community. Each member of the archaic nobility was associated with an animal, which was an ancestor, or was simply used as an ensign. "The conclusion, therefore, is that the totemic clan, as part of the political constitution of the tribe as a whole, really centres round one family, that family which claims direct descent from the animal ancestor that gave rise to the clan."

MARRIAGE RULES.

Mr. Perry's investigations point to three stages of development of marriage rules: (1) marriage forbidden between members of the same moiety, (2) of the same clan, (3) between blood relatives. It appears that the practice of intermarriage formerly held between the two branches of the ruling groups of the archaic civilization, and was extended to the clan system; but when the clan grouping disintegrated, marriage was forbidden within certain degrees of kinship; the earlier stages did not prevent the marriage of certain kin.

The main thesis propounded by Mr. Perry may be summarized very briefly in the statements that everywhere aboriginal people were essentially peaceful and had a very primitive culture. Then the carriers of the archaic civilization arrived in their search for wealth and Givers of Life; they too were peaceful and had a sun-cult with sky deities. The old regime was suddenly closed by the rising to power of war chiefs, who naturally adopted war-gods, and the resultant turbulence induced cultural degeneration. Warlike tendencies, on the whole, have dominated the world ever since the Children of the Sun were destroyed by the Inheritors of the Underworld.

Enough has been said to give a general idea of the cultural elements which characterized the main features of the archaic civilization, which Mr. Perry traces back to the Fifth and Sixth Dynasties of ancient Egypt—*i.e.*, about 2750–2475 B.C.

The reason assigned for the voyages in the early dynasties was to procure the materials for mummification and funeral rites, which objects were regarded as "Givers of Life," as well as to obtain gold, pearls, and other valuables, which themselves had a ritual significance. It would then follow that this quest originated in Egypt and proceeded thence to contiguous countries and lands afar off.

Accepting the statements of Professor Elliot Smith, we have to assume that the Semitic-speaking Phoenicians exploited South India, but left no trace of their language or distinctive religion. The same applies to Further India and Indonesia. The occurrence of certain funeral customs in San Cristoval, in the Solomons, suggests a very close connection with Egypt of the Sixth Dynasty; but here, again, Semitic cultural influences are lacking, and the peoples speak an Austronesian language; the same obtains for the rest of Melanesia, and for Polynesia and Micronesia. The type of mummification found in Torres Straits and Northern Australia, according to

Professor Elliot Smith, shows signs of Egytian technique of the Twenty-first Dynasty, about 1090–945 B.C., which points to a very much later cultural movement than that which we are now considering. The civilization of ancient Mexico as summarized by Mr. Perry shows such close resemblances with the archaic civilization as to afford a strong presumption that it was derived therefrom, and also that the culture-bearers had not remained for any appreciable time in Polynesia; indeed, some cultural features seem to indicate that there was direct and rapid communication between Mexico and southern Asia. Here again the physical characters and the languages of Central America do not now present any Phoenician characters.

THE MIGRATION FROM EGYPT.

If we accept the main thesis advocated by Mr. Perry of the eastward spread of a complex civilization from Egypt four to five thousand years ago, the mechanism of this spread requires to be critically studied, the linguistic difficulties faced, and a relative chronology suggested.

The first stepping-stone, India, of this spread presents no difficulty. It seems impossible to escape from the conclusion that the first extension of the archaic civilization in Melanesia was due to Austronesian-speaking peoples originally from the mainland of Asia and immediately from Indonesia. There is sufficient evidence that the Polynesians came from Indonesia, the earlier of them, perhaps, with an intermediate stage in Melanesia. It is difficult to avoid the conclusion that Melanesia was visited directly by Maritime Armenoids, Phoenicians, or whatever they may be called; indeed, as we have seen, there appears to be a trace of this physical type among existing Polynesians. The language difficulty is sufficient to preclude the view that Polynesia was originally colonized by the Phoenicians or allied voyagers. The Rev. Dr. C. E. Fox has found that the members of the Araha clan of San Cristoval embalm their dead chiefs and place them in cavities hollowed out within mounds, often made of stone and shaped in pyramidal form with flat tops, so that they resemble the mastabas of early Egypt. From the surface of the mound of San Cristoval a shaft leads down to the recess within which the body lies. On the top of the mound there is often a structure consisting of a table-stone resting on three or four uprights, having the characteristic form of a dolmen. On or by the side of this dolmen stands an image in human form, carved out of coral or stone, which is believed to represent the dead man, and to act as the abiding-place of the soul which left his body at death. . . . The statue is in a seated posture, and at the back of the head a pigtail-like structure reaches down to the stone surface upon which the image is placed, thus reproducing a feature of the statues of Cheops, Chephren, and Mycerinus, the builders of the great pyramids of Egypt (Rivers, 1922, p. 16) [*i.e.*, Fourth Dynasty kings: Cheops, 2900 B.C.].

The parallelism of this and of other customs referred to by Dr. Rivers to similar customs of ancient Egypt of the Pyramid Age is so striking that it cannot be ignored; indeed, Rivers had elsewhere said, "These funerary customs bear so close a resemblance to those of Egypt as to leave no reasonable doubt that travellers imbued with the essential ideas of Egyptian culture reached San Cristoval and introduced not only burial in pyramidal structures, but also the custom of erecting a statue to serve as the abiding-place of the ghost of the dead man" (1920, p. 68).

The exact way in which this and other customs reached Oceania is at present obscure, but a great deal of exciting information is constantly coming

to light, and it is evident that we have only just begun to appreciate the extreme complexity of the problems connected with the human occupation of the Pacific.

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THE JURASSIC ROCKS OF NEW ZEALAND.

The Jurassic Rocks of New Zealand, by C. T. Trechmann; with an Appendix on "Ammonites from New Zealand," by L. F. Spath. (*Quart. Journ. Geol. Soc.*, vol. 79, pp. 246–312, pls. 12–18; 1923.)—Dr. Trechmann's valuable account of the Trias in New Zealand, published in 1918, has made New Zealand geologists eager for the publication of his paper on the Jurassic, which was read before the Geological Society in 1921. Dr. Trechmann's conclusions as to the age of the various beds he describes are supported by identifications of the brachiopods by Mr. S. S. Buckman, and of the ammonites by Dr. Spath, than whom no more authoritative palaeontologists in their respective specialties could be found.

The Jurassic in New Zealand exhibits a much greater vertical range of marine fossiliferous deposits than the Triassic, the horizons identified ranging from the lowest Lias to the uppermost Jurassic (Tithonian), while geographically the Jurassic rocks occur over a rather greater length of the two Islands than the Trias. Dr. Trechmann has not, of course, been able to examine all this great extent of country, but has visited only selected localities where fossils were known — viz., the Hokonui Hills and Kawhia Harbour—and, in addition, had access to collections made at Waikato Heads and from the coast section south of Nugget Point. Of these localities the only one described in any detail is Kawhia Harbour, the account of which was written by Dr. P. Marshall. The paper, therefore, is rather a description of a collection of Jurassic fossils from New Zealand than a study of the Jurassic rocks. That has still to be made. Meanwhile Dr. Trechmann's paper will facilitate the naming of fossils and the identification of horizons. It should now be possible, thanks to Dr. Trechmann's two papers, for a student trained in New Zealand to attempt detailed stratigraphical studies on any locality where marine Triassic or Jurassic fossils are found.

J. A. T.

CRETACEOUS AND TERTIARY FORMATIONS OF NEW ZEALAND.

THE UNCONFORMITY BETWEEN THE CRETACEOUS AND TERTIARY FORMATIONS OF THE EAST COAST OF THE NORTH ISLAND.

By M. Ongley, M.A., B.Sc.

Confusion in New Zealand Stratigraphy.

The Upper Cretaceous and Tertiary sedimentary rocks of New Zealand have been examined often, in many places, and by many observers; they have always been, and are to-day, more discussed and written about than any other New Zealand rock-series; and as in the past, so still to-day, every classification differs from the others. This obviously implies that elements of difficulty and confusion are involved; yet, as a rule, each observer asserts that the problem is simple and confidently advances his own explanation as evidently conclusive. The extent of the disagreement and confusion is appalling, especially for any one who tries to learn New Zealand geology from the book; it is well shown by Marshall, Speight, and Cotton in *The Younger Rock-series of New Zealand* (Marshall, Speight, and Cotton, 1911). The stratification is simple, and the lack of agreement among observers is due more to confusion than to difficulty, and centres round doubtful and difficult points of correlation on insufficient evidence rather than round questions of rock sequence or stratigraphy. The early field-workers—McKay, Hector, Hutton, Cox, and others—recorded in their reports many unconformities, but gave little or no evidence to support their statements. For example, Hector, in reporting on the east-coast district in 1877, wrote, "They [the Cretaceo-Tertiary series] have an enormous thickness, probably not less than 7,000 ft., and nearly everywhere are inclined at high angles, and have been much faulted and disturbed before they were planed down by the action of the sea and overlaid by the foregoing Tertiary strata" (Hector, 1877, p. xvii), and gave no evidence at all and did not mention where any contact could be seen. When the early reports were compiled into accounts of the geology of New Zealand, the different sets of strata and the different unconformities described in them were, perforce, correlated on scanty data, so that different authors were able with equal evidence or equal lack of evidence to tabulate the beds differently. This led to much dispute, much citing of doubtful evidence, and such disagreement that when Marshall, Speight, and Cotton reviewed the evidence in 1911 they found that every unconformity described by any author had been unrecognized by the majority of those who had examined the section. On examining the unconformities previously mentioned they found many had been put in on little evidence, and that the evidence was in no case decisive. From this they recognised the necessity of caution, and decided to treat the whole series as conformable until an unconformity should be convincingly demonstrated. In support of the conclusion that the strata were conformable they elaborated the theory that the beds represented a simple sedimentary cycle with shallow-water beds at the base overlain by beds indicating deepening water till the limestone was deposited, and above the limestone by beds that indicated

progressively shallowing water. This revolutionary hypothesis was simple and attractive, and has been so ably supported by Marshall that it remains in vogue to-day. In 1916 Morgan attempted to refute the hypothesis of a single cycle of sedimentation, and compiled "Records of Unconformities from Late Cretaceous to Early Miocene in New Zealand," maintaining, in conclusion (3), that "in all parts of New Zealand there is a decided unconformity between the Miocene and any Eocene or older rocks present" (Morgan, 1916). Unfortunately, this agreement in the old reports is only apparent; for the observers who took the field with the hypothesis that the Cretaceo-Tertiary was unconformably overlain by the Miocene naturally interpreted every irregularity as the break below the Miocene: that is, if A found an irregularity below the limestone, and B found an irregularity below the sandstone, A and B would class all above the irregularity as Miocene, and would apparently agree that there was a break below the Miocene. Such agreement is delusive, and the geologists do not agree in accepting any unconformity. In the same year in which Morgan's statement was published Thomson wrote, "New Zealand geologists are not agreed as to the presence or absence of unconformities between certain rocks, and they are not agreed on the correlations that should be made between the rocks of different localities" (Thomson, 1917, p. 29); and a year later repeated, "There is no single unconformity that has been proved to be common to all districts" (Thomson, 1917, p. 404). Still, Morgan's conclusion that "There are various local unconformities in the rock successions discussed; some observers have hastily assumed one or more of these to be major unconformities, whilst others have denied their existence altogether" (Morgan, 1916, p. 15) is a fair summary of the position.

Since that time Marshall has written many papers all confirming the hypothesis of a simple cycle of deposition; his ideas have become current. His latest statement of the hypothesis is in his paper "Early Tertiary Molluscan Faunas of New Zealand," where he wrote, "Soon after I had begun an investigation of the geology of the Upper Cretaceous and Tertiary formations of New Zealand, more than ten years ago, I was forced to adopt the view that there had been continuous sedimentation in the New Zealand area from the Upper Cretaceous (Senonian) to the Pliocene. In all districts where there has been a close examination of the stratification it is agreed that no hiatus of any importance can be discovered, and in nearly every case it is admitted that the series of younger rocks is not interrupted by any period of discontinuity" (Marshall, 1923, p. 116).

In opposition to Marshall's theory little recent evidence has been cited except in the Geological Survey Bulletins. Those who have endeavoured to refute Marshall's contentions have generally been shown to be in error, and his latest opponent, Thomson, in his paper on "The Notocene Geology of the Middle Waipara and Weka Pass District" (1920, p. 407), conceded that "Marshall has successfully demonstrated the general fact that the younger rocks in most localities form an accordant series, without important angular unconformities between the various beds; and, further, that the beds in any one locality are those of a sedimentary cycle with progressive characters of depth of deposition towards the middle limestone members" (Thomson, 1920, p. 407). Further, in criticizing Marshall's generalizations Thomson could adduce no stronger evidence than this: "Angular unconformities are rarely seen, but are nevertheless not absent; while palaeontological disconformities are also present. For instance, in the Kaiwhata River, east Wellington, there is a conglomerate containing

boulders of Cretaceous sandstones, greensands, and basalts, similar to those outcropping near by, and also boulders of shell-rock, apparently derived, containing Oamaruian fossils, including *Pecten huttoni*. The conglomerate has a mudstone matrix and passes up into mudstones. There is obviously an unconformity here between two members of the younger rock-series. Morgan and Henderson have described unconformities in numerous places, and it cannot reasonably be doubted that they occur. Disconformities, or planes representing periods of standstill and non-deposition, are also known —*e.g.*, that between the Hutchinson Quarry beds and Ototara limestone" (Thomson, 1920, pp. 407–8.) As Marshall had already adversely criticized the breaks described by Morgan, and Henderson's had not been re-examined or confirmed, and as Marshall and others maintained that the Oamaru and Weka Pass sections were conformable, the only evidence left was Thomson's Kaiwhata break, then mentioned for the first time. On the evidence presented up to then by Marshall and Thomson the theory of a simple sedimentary cycle was admitted, and no unconformity was established.

The object of this paper is to produce evidence of unconformity, and to demonstrate that the Cretaceous and the Tertiary are separated by an unconformity in the east coast. From that it may be inferred that, as this section was confidently asserted to show complete conformity, some of the other sections similarly described may repay re-examination, and may, when mapped, show that the simple explanation is not the correct one. But first, as different observers have examined the same sections—*e.g.*, Gisborne and Weka Pass—and some have described them as perfectly conformable and others have considered them unconformable, it is necessary, in order that we may not misunderstand one another, to recognize that some of the disagreement is due to confusion in the use of terms, and that we may not be misunderstood it is necessary to make plain in what sense the words are used in this paper.

Different Uses of the Term "Unconformity."

Lyell defined and figured "conformable" and "unconformable" in his *Principles of Geology* (page 438) as follows: "When the planes of one set of strata are generally parallel to those of another set which are in contact they are said to be conformable. Thus the set *a*, *b*, Figure 139, volume 4, page 120, rest conformably on the inferior set *c*, *d*; but *c*, *d* rest unconformably on E." And in *The Student's Lyell*, by Judd, page 99, we find: "Conformably and unconformable stratification: When strata rest upon one another horizontally, or with the same dip, they are conformable. But strata are said to be unconformable when one series is so placed over another that the planes of the superior repose on the edges of the inferior (see figure 106)."

In accord with Lyell's definition of "unconformity" we find Irving, in the United States *Seventh Annual Report*, making the distinction between unconformity and erosion interval as follows (p. 390): "The term 'unconformity' applies to that geological structure which obtains when one group of strata lies upon another in such a manner that the layers of the two groups are not parallel" (Irving, 1888, p. 390). And in discussing the erosion interval he wrote: "Being raised above the sea a given area may, of course, remain through an indefinite length of time without receiving new material. Inasmuch as this raising above the sea may be produced without folding of the strata, it follows that upon further submergence new material

may be deposited over the old in an essentially conformable manner. In such cases, however, the indications of the former existence of a land surface and of the intervention of a period of erosion will often be met with in the midst of the finished pile of strata. The structures which result are often spoken of as unconformities by erosion. The phrase is an unfortunate one, however, since the word 'unconformity' distinctly implies a lack of parallelism between the strata on opposite sides of the break, and, moreover, all true unconformities indicate folding as well as an intervening erosion" (Irving, 1888, p. 392). The distinction was then clearly made; the discordant breaks were called "true unconformities," while those in parallel strata were styled "erosion-intervals." As pointed out by Blackwelder, "it was felt that the very word 'unconformity' involved the idea of angular discordance between the beds above and below, and hence that any interruption between parallel beds must go by another name" (Blackwelder, 1909, p. 289). Moreover, it was so by definition. Nevertheless he showed that Le Conte in 1890 defined breaks between discordant beds and eroded surfaces in parallel strata as merely two varieties of unconformity, and that the wide use of "unconformity" tended to become general.

In his *Text-book of Geology*, in distinguishing overlap from unconformability, A. Geikie wrote: "In overlap there is no break in the sequence of formations, the strata that overlap follow on continuously upon those which are overlapped. But in unconformability there is a break in the succession, the overlying rocks have been laid down on the previously uptilted and denuded edges of those below them" (Geikie, 1903, p. 653). This is in agreement with Lyell; but on page 821, in discussing unconformability, he wrote: "In rare cases an unconformability may occur between two horizontal groups of strata. . . . In such a case the upheaval must have been so uniform over some tracts as not to disturb the horizontality of the lower strata, so that the younger deposits lie in apparent conformability upon them."

We find instructive illustrations of the strict use of "conformable" in Pirsson and Schuchert's *Text-book of Geology*, pages 892 and 898, in one of which they show a "conformable contact of Cretaceous shales on Devonian limestones," and in the other a "conformable contact" between the Cretaceous and the Eocene—which is, however, a most important erosion interval, above which not one of the 168 species of Cretaceous mollusca survived (Pirrson and Schuchert, 1915). The wide use of the term "unconformity" is opposed to Lyell's definition; it has caused and is causing much confusion, and as it is quite unnecessary it cannot be justified. Unconformity as defined by Lyell and as recognized in standard dictionaries means non-conformability or non-parallelism of two sets of strata; this non-parallelism was shown to indicate that a period of erosion had intervened in the sedimentation; and from confusion between the physical non-parallelism of the strata and the historical or erosional significance thereof "unconformity" began to be used for any interval of erosion between parallel or non-parallel formations indifferently. As a result we find that to-day, when an author says that one set of strata is unconformably overlain by another, we cannot form any clear image of what he means. That this wide use of the term is loose, confusing, and unwarranted has been felt by many writers, as is shown by their introducing still more new terms; but none of these newer systems of nomenclature has come into use, and all are unsatisfactory because they commit the fundamental error of using "unconformity" for strata that conform in strike and dip. Hence the

word "disconformity" was coined by Grabau in 1905, and "unconformity" reassigned to its original use, or used widely to include the original and the new by making "disconformity" a subdivision of "unconformity." As pointed out by Crosby (Crosby, 1912, p. 295), the word "disconformity," with the prefix "dis," implying divergence, is even more unfortunate. But, while rejecting "disconformity," Crosby lapsed into the popular error of using "unconformity" for all types of erosion interval, and found it necessary to introduce "parunconformity" and "clinunconformity." Similarly, Heim, as quoted by Crosby, had a new scheme :—

accordanz = conformity (strata parallel).
disaccordanz = unconformity (strata divergent) = clinunconformity.
paenaccordanz = approximate conformity (strata nearly parallel)= parunconformity.

This scheme, while correctly placing the prefix "dis," introduced an objectionable, unwanted middle term to signify some meaning between parallel and divergent where there is no room for a term, for strata must be either parallel or divergent. Other unwanted neologisms, such as Schuchert's "non-conformity" as distinct from "unconformity," and "evident" and "non-evident disconformity" (Schuchert, 1915, p. 292), and the "stratic" and "structural unconformity" of Grabau (Grabau, 1913, p. 821), are readily dispensed with without inconvenience by using "unconformity" as Lyell defined it, and describing without ambiguity the phenomena of parallel erosion intervals in the old simple terms. The term "erosion interval" has been used and can be used in two senses corresponding to the two senses of unconformity—that is, it may signify (1) the erosion gap or contact between the two sets of strata, and (2) the period or interval of erosion between two periods of sedimentation. With these terms correctly used we can avoid confusion and error, and not stultify ourselves by admitting as scientific such usages as "the strata conform in strike and dip, but are unconformable," and "the strata are perfectly conformable in strike and dip, but are disconformable."

CONCEPTIONS OF THE NATURE OF EROSION INTERVALS.

The errors caused by the ambiguous uses of "unconformity" are numerous; but, as they are due to confused writing and not to obscure stratigraphy, they can be corrected. After the first cause of confusion has been got rid of there remains such difference of opinion about the significance of any break as was indicated by Morgan in his statement, "Some observers have hastily assumed one or more of these [local unconformities] to be major unconformities, whilst others have denied their existence altogether." As far as the east coast is concerned it is not correct to say that some have denied their existence altogether, for Marshall, Adams, and Clarke all recognized some irregularities, but considered them trivial. There is authority for each view. The extracts quoted from Lyell, Judd, Geikie (p. 653), and Irving describe "unconformity" as a conspicuous break in the stratigraphy; and we have also the following from Geikie (p. 641): "In the instances [of contemporaneous erosion] cited it is evident that the erosion took place, in a general sense, during the same period with the accumulation of the strata. For, after the interruption was covered up, sedimentation went on as before, and there is usually an obvious close sequence between the continuous strata. Though it may be impossible to decide as to the relative length of the interval that elapsed between the formation

of a given stratum and that of the next stratum which lies upon its eroded surface, or to ascertain how much depth of rock has been removed in the erosion, yet when the structure occurs among conformable strata evidently united as one lithologically continuous series of deposits we may reasonably infer that the missing portions are of small moment, and that the erosion was merely due to the irregular and more violent action of the currents by which the sediment of the successive strata was supplied. The case is different when the eroded strata, besides being at a different angle from those above them, are strongly marked off by lithological distinctions, particularly when fragments of them occur in the overlying deposits."

These extracts indicate that minor breaks are merely irregularities of sedimentation, and that unconformity necessitates a difference of altitude, a marked break, and a rock difference. On the other hand, American literature shows that scarcely detectable breaks may be of great significance. In the Coalinga Bulletin (Arnold and Anderson, 1911) are several examples. On page 75 in the general description of the Post-Eocene formations we read: "The Miocene, Pliocene, and Early Pleistocene are represented . . . by a series of formations that form a group by themselves distinct from the older formations. The first impression received upon viewing the field is that the later Tertiary beds form one continuous succession, and it is therefore natural to take up first a brief review of the whole series before passing to the more detailed descriptions of the different divisions of it, which on closer study are found to be separable from one another. The periods following the Eocene are here represented by a great series of sandstone, shale, and conglomerate beds, all tilted at about the same angle, having usually similar characteristics, and presenting an appearance of conformity and intergradation. By means, however, of discontinuous fossil faunas, distinguishable lithologic groups, the absence in some places of formations or zones known elsewhere, as a result of erosion, and the overlapping of later beds, and the appearance of fragments of older formations within younger ones, several important breaks may be definitely made out, which prove the intervention of periods of time during which land conditions existed over wide areas or locally."

With slight modification this summary so aptly describes the New Zealand Tertiary that it is worth attention.

Other pertinent extracts are (p. 58): "However, in spite of the apparent transition between the shale of the Cretaceous and that of the Eocene . . . it is believed that they are separated by an unconformity." (P. 98): " . . . it would be a matter of great difficulty to determine at what horizon the unconformity exists." (P. 164): "That little reliance is to be placed on the appearance of angular conformity is made clear at several points . . . where an appearance of such a relation . . . is to be found only at a short distance from points where the contact displays pronounced discordance in dip."

These extracts, referring to California, are useful, because Marshall, in his paper on "Relations between Cretaceous and Tertiary Rocks" (Marshall, 1916, p. 107), referred to California as having a conformable Cretaceo-Tertiary series. We have numerous other such references, of which the following, from *Bull. Geol. Soc. Am.*, vol. 22, p. 462, will serve as an example :—

"Evidence of sea-withdrawal has been discovered in many parts of the stratigraphic sequence where none had previously been suspected. That is not because geologists then were either less diligent in their field-work or

less keen observers than are those of the present generation, but because they had bound their minds and perceptions by certain beliefs, and because they knew and employed only those criteria that under these conceptions alone seemed competent. They recognized shallowing of the seas and shores by the presence of ripple-marked and sun-cracked beds, by trails of creeping things, by tracks, impressions of raindrops, conglomerates, and other phenomena commonly seen along the present shores of the sea; and they knew that tilted marine deposits, the edges of which had been planed down and subsequently covered with approximately horizontal beds, signified previous elevation and subaerial erosion. Presently unconformities between horizontal beds were recognized, and, at first tentatively, then more confidently, interpreted as general elevation into land and resubmergence without conspicuous folding. And so it has gone on and on, perhaps unconsciously, to the present time, when some geologists at least postulate land areas at almost all such times and places as are indicated by imperfections in the sequence of marine sedimentation. Conviction in this matter of frequent alternation of emerged and submerged conditions seems, indeed, to have progressed so far that the burden of proof now lies with those who deny the proposition rather than with those who affirm it.

"*Physical Criteria of Stratigraphic Unconformity.*—Of the various physical phenomena indicating emergence, stratigraphic unconformities are the most common and most reliable. But it is only when the contact line is boldly irregular, or when the discordance in bedding is great enough to be easily measured, that the unconformity is immediately distinguishable from the average bedding-plane. Those strongly marked cases are relatively few as compared to the many that are far from conspicuous and which often require corroborative evidence before their true nature can be established. The characteristics of clearly defined unconformities are so well known that further description seems unnecessary. We will therefore proceed at once to the discussion of the more obscurely manifested areas.

"Every sharp faunal or lithologic break suggests a stratigraphic hiatus, and hence an unconformity and preceding sea-withdrawal." (Ulrich, 1911, pp. 462–63.)

These extracts contrast with the previous set and show that an inconspicuous break may be important; and as an example the Cretaceous-Tertiary contact near Reims, described and figured in the *Bulletin de la Société Géologique de France*, quatrième série, tome douzième, pp. 757–58, 1912, may be cited.

Usage in New Zealand.

But most of the geology of New Zealand has been done by geologists who expected to find a conspicuous break marking erosion intervals. Marshall, Speight, and Cotton, in the *Younger Rock-series of New Zealand*, wrote (p. 384): "It is, however, obvious that an unconformity between Cretaceous and Miocene rocks . . . should be of such a marked nature as to be a conspicuous feature in all the clear sections in the districts in which the rocks are developed." Observers beginning with this hypothesis and using "unconformity" as Lyell used it naturally arrived at the conclusion that there was no unconformity. Yet the evidence gathered in the east coast compels the conclusion that the Cretaceous is separated from the Tertiary by conspicuous Lyellian unconformity, the nature of which will be indicated in the following notes.

EARLIER ACCOUNTS OF THE EAST COAST GEOLOGY CONSIDERED.

In the *Younger Rock-series of New Zealand* Marshall referred to the Gisborne district as follows: "In the Poverty Bay district a complete series of Cretaceous and Tertiary rocks has been described by McKay. This district has, however, lately been worked in detail by Adams, who classed all the rcoks of Upper Miocene age, stating that no marked unconformity was observed between any of its members. One of us has examined the sections in this area in great detail, and is positive that no unconformity was shown in the many miles of continuous sections displayed" (p. 393). As it is to the rocks of that district and the adjacent area we wish to refer, it is advisable to see how the other geologists have described the rock sequence from the Cretaceous to the Tertiary there.

In his 1874 visit McKay overlooked the contact and included the lowest Tertiary, the "*Leda* marls," as he called them, with the Cretaceous chalk-marls in the Cretaceous Tertiary. In his 1877 report Hector likewise included the *Leda* marls in the Cretaceo-Tertiary, but described the Cretaceo-Tertiary beds as having been "much faulted and disturbed before they were planed down by the action of the sea and overlaid by the foregoing Tertiary strata" (Hector, 1877, p. xvii). In 1887 McKay reclassified the strata, placing the *Leda* beds in the Lower Miocene, and including in the Cretaceo-Tertiary chalky limestone with the Amuri fucoid greensands, black shales, grey and blue marls. As to the unconformity he wrote: "The Akuaku (*Leda*) beds were formerly regarded as belonging to the Cretaceo-Tertiary formation; but the same beds at the mouth of Waipiro Creek rest unconformably on the Secondary rocks, and in the Ihungia rolled pebbles containing fragments of *Inoceramus* are found in the gravels that form a considerable part of the series in that part of the district" (McKay, 1887, p. 210–11). In 1901 McKay abandoned the Cretaceo-Tertiary hypothesis and described the basal Tertiary as marked by the igneous conglomerate containing "fragments of white limestone and spherical concretions derived from the Cretaceous rocks, proving the unconformable relationship of the two formations" (McKay, 1901, p. 24).

But after McKay had obtained this evidence and published this conclusion in 1901 it was discredited by later workers. Adams in 1908 classified the Cretaceous and Tertiary strata together, "for the reason that stratigraphical unconformities are by no means apparent, and such palaeontological evidence as is at present available does not appear to warrant their being referred to more than one series. Mr. Alexander McKay, however, considers the lower beds to be conformably older and of probable Cretaceous age"* (Adams, 1908, p. 32). Adams recognized four different formations, but did not find any Cretaceous fossils, so he classed them together. In his 1909 annual report and in *Bulletin 9* Adams maintained that there was no break; but he divided the beds into upper and lower series, between which, he said, no contact was seen (Adams, 1909, p. 15), and subdivided the upper series into two parts, the upper of which contained shore-line conglomerates in which Adams recognized portions of concretions derived from older beds of the same series. Notwithstanding this, Adams grouped the beds into one series. In the same bulletin Marshall, who wrote the palaeontological section, maintained that in the Subdivision no evidence in favour of a Cretaceous age for any of the rocks was found, and continued: "It is also stated by Mr. McKay that the lowest bed of his Lower Miocene is a

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* Parliamentary Paper C.–9, 1908, p. 32.

conglomerate of crystalline rocks. Within the Whatatutu Subdivision an outcrop of this conglomerate on the Waipaoa River opposite Waipaoa Station was carefully examined. The underlying claystones contain *Limopsis aurita*, and differ in no way from the claystones elsewhere. Lastly, the rocks at the oil-spring on Waitangi Hill are said to be of Cretaceous age. Here *Limopsis insolita*, *Terebratella gaulteri*, and *Calyptraea calyptraeformis* were found. These are similar to fossils found elsewhere in the series. Boulders with *Glycymeris* and associated fossils were found by McKay in the river-gravels in 1873. The occurrence of these was explained by him as derived from a series of rocks that was supposed to overlie the Cretaceous rocks of the area. The field-work has shown that rocks with abundant *Glycymeris* remains occur on a level with the floor of the Waingaromia Valley, and no unconformity separates them from the lowest rocks of the district." (Adams, 1909A, p. 23.)

In 1912, in examining the Waiapu district, Clarke came to the same conclusion as Marshall and Adams had done at Whatatutu, grouped all the beds into one series, and regarded the gritty conglomerate bands he saw as indicating merely local unconformity. To show there were Cretaceous fossils in the district Mr. Morgan, in 1914, collected *Inoceramus* specimens three miles outside the Whatatutu Subdivision, in clay shales a few chains below Motu Falls, similar to the beds of Adams's Mangatu series. In *Bulletin 21* it was shown that the erosion interval is marked by a conglomerate in the Mangatu and Waipaoa in the following extracts: "At many points in the lower Mangamaia the Wheao (Lower Tertiary) rocks contain small rounded pebbles of chalky limestone and clay-shale. On the right bank of the Mangatu, at a bend about 10 chains below the bridge on the Mangamaia Road, steeply dipping beds of this series contain immense numbers of fragments of chalky and argillaceous limestone, as well as a few rounded pebbles of clay-shale. Generally these fragments, which are contained in several distinct layers, are angular or subangular, and the rock presents the appearance of a breccia. Although these beds are obviously fault-involved, the breccia is apparently not of cataclastic origin. The matrix is quite as hard as the embedded fragments, from which it differs in colour and texture; it is not a pug, but appears to be a sediment with planes of deposition. The uniformity in the size of the fragments is also an argument in favour of the sedimentary origin of the rock. The shape of the included fragments is similar to that assumed in stream-beds by the chalky limestone, and presumably the stresses that produced fissility in that rock had operated prior to Wheao times." And (p. 41), "Near Waipaoa Station, in the north-eastern corner of Mangatu Survey District, the lower part of the Tawhiti series contains thick beds of conglomerate in which the pebbles for the most part consist of crystalline rocks. . . . The conglomerates overlie argillaceous sandstones and mudstones belonging to the same series, and beneath these are beds of very fine conglomerate and sandstone containing carbonaceous matter. The actual base of the series is a layer of breccia from 4 in. to 6 in. in thickness. This rests upon a massive bed of strongly calcareous claystone belonging to the Mangatu series, and consists of angular fragments of the underlying rock set in a matrix of grit of the same material." (Henderson and Ongley, 1920, pp. 36 and 41.)

The conclusions arrived at by Marshall and Adams are untenable. The finding of *Limopsis* below the conglomerate indicated that some of the beds below the conglomerate were Tertiary, and this can be reconciled with McKay's observations as reported in 1887 and 1901, for he did not say

that all below the conglomerate was Cretaceous, as suggested by Marshall. McKay's words are, "The same beds [Lower Miocene] have a large development from Tokomaru Bay north-west to Puketiti and west to the Mata River, and consist of marly and sandy clays, sands, and conglomerates. The finest sections of these beds are seen in the banks of the Ihungia near Puketiti, and for the next four miles along the course of the stream to the north. The remarkable feature of these beds is the *contained* conglomerates, which form thick beds at frequent intervals, and are to a very large extent formed of crystalline rocks" (McKay, 1887, pp. 211–12). And, "These [Lower Tertiary beds] extend throughout the district from its southern limit to Waipiro Bay and the Waiapu Valley abreast of the eastern spurs of Hikurangi Mountain. The lowest beds in the northern part are a coarse conglomerate or breccia consisting mainly of crystalline rocks principally composed of hornblende which often show a schistose structure. These rocks, between the Mata River and Tawhiti Mountain, on the north side of Tokomaru Bay, are of great thickness. In this part they contain fragments of white limestone and spherical concretions derived from the Cretaceous rocks, proving the unconformable relationship of the two formations. The dark hornblende boulders reach south into the valley of the Waipaoa above the junction of the Mangatu, and in the deep gorge above this junction the river-gravels show various hornblendic boulders up to fully 2 ft. in diameter. The Waipaoa Gorge has been excavated in sandy clays and sandstones belonging to this formation. *In the gorge the source of the hornblendic boulders is not seen*, but to the west, where this formation shows its lower beds resting on the upper division of the Cretaceous rocks, a thickness of the hornblendic breccia conglomerate is present, and by means of the tributary creeks debris from the same finds its way both into the Waipaoa and the Mangatu" (McKay, 1901, p. 24). As in these statements McKay says that the conglomerate in the Ihungia is contained in the Tertiary and that he did not see the conglomerate outcrop in the Waipaoa Gorge, there is no conflict between McKay's observation and Marshall's that *Limopsis aurita* occurs in the claystone below the conglomerate. Marshall did not record how far below the conglomerate the fossil occurs; but the field-work done shows that it must have been close, for the unconformity as recognized by McKay and confirmed by the later field-work shows that the unconformity is close below. And as pointed out by many authorities, most recently by Twenhofel and Edwards (*Bull. Geol. Soc. Am.*, vol. 32, p. 40), contrary to the statements in the text-books, the basal beds above unconformities are generally fine and the conglomerates occur higher up. Their paper shows that "In many text-books of geology the initial deposits over an unconformity are represented as conglomerates or coarse sandstones, and the impression is left that such are the general accompaniment of an unconformity. Observations made on many geologic sections show that such is not always the case, and that the initial deposits are in many cases fine clastics, while coarser clastics are altogether wanting or occur some distance above the initial strata," and concludes "that gravels and coarse sands are not necessarily the initial deposits of an invading sea, even under conditions of considerable relief, and that it is equally as probable that the initial deposits above an unconformity should be fine clastics."

Similarly Ulrich, writing on "Stratigraphic Hiatuses," said: "*Frequent absence of clastic material at base of overlapping formations not extraordinary.* That in many good exposures scarcely a trace is to be seen of the imperfectly

stratified initial deposits referred to in preceding paragraphs [littoral conditions recorded by initial deposits] will seem to many a strong argument against the assumption in such cases of emergent conditions. In other words, they may claim that in the absence of subaerially produced clastics, and perhaps of other clear evidence of land decay and erosion, other possible causes of stratigraphic hiatuses should be given preference. . . . The mere absence of distinctive shore deposits surely does not outweigh all the other evidence on which small low lands and shallow seas is inferred. This negative evidence goes no further than to suggest that the lands were too low and the seas too shallow to favour the development and accumulation of such material. . . . With slow submergence of such a land the advancing sea must have taken nearly the whole of the residual matter into suspension. Some of it may have been swept into whatever hollows there were, but most of the finer particles were probably carried seaward and later deposited with the normal sediments of the time. If proper clastic material was available, then it was arranged to form a beach. If not, then whatever littoral fauna was present attached itself to or bored into the bare rocky floor, and was finally buried beneath normal marine sediment in which land detritus constituted but an insignificant part." (Ulrich, 1911, p. 457.)

The section described in *Bulletin 21*, pages 41–42, and numerous sections examined during field-work, afford illustrations. Some are described in the second section of this article.

(To be continued.)

THE NEW ZEALAND MINNOW.

NOTES ON THE LIFE-HISTORY OF THE NEW ZEALAND MINNOW (THE ADULT WHITEBAIT), *GALAXIAS ATTENUATUS*.*

By W. J. Phillipps, F.L.S., F.R.G.S.

The adult minnow, which migrates down-stream during February and March, is at this season known to Hokitika fishermen by the seemingly misapplied appellation of "cowfish." It is, however, on account of the fact that, when captured, milk-like ova or semen comes away from the body of the fish that this name has been so readily adopted. So far it has been generally conceded that these fish were on their way to the sea to spawn, for without doubt larval specimens have been taken at sea on numerous occasions. Mr. W. B. Braddon, of Hokitika, who has made a long study of fresh-water fishes and fisheries, kindly supplied me with this extract from his diary :—

"February 10, 1911.—On this day I first witnessed the spawning of the adult minnows. They were seen to be congregating together, stirring up the mud between the stones close to the bank on which I was standing. This point was half a mile from the open ocean, in the estuary of the river. It was high tide at the time, and the water was more salt than fresh. The

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* See also W. J. Phillipps, Life-history of the Fish *Galaxias attenuatus*, *Australian Zoologist*, vol. 1, pt. 7, 1919.

muddy water prevented close observation, but the fishes appeared to be whirling over each other, as their backs continually rose above the surface. The spawning fish made no attempt to escape when an endeavour was made to catch them, and specimens were lifted out of the water while ova came away freely. The process was observed for half an hour."

Mr. E. J. Lloyd, Hokitika, gave me an account of the spawning which agreed in all details with the above. Mr. W. McNeil, of Westland, found the minnow spawning nearly a mile from the mouth of the Mahinapua Creek. The Hokitika River has a tidal reach of one mile and a half inland, while the tidal reach of the Mahinapua Creek is about three miles. Several Hokitika fishermen informed me that minnows spawned among rushes on the mud-flats near the estuary of the river, and were to be seen in immense shoals stirring up mud during February and March.

The accompanying figure is drawn from an example 4 in. long secured by Mr. Braddon in the estuary of the Hokitika River in March, 1921, and presented to the Dominion Museum. The anal fin appears to be slightly larger than usual, and the origin of the ventral a little farther back. This species is distinguished from other members of the genus *Galaxias* by its short pectoral fin, which reaches less than half the distance from its origin to the origin of the ventral.

[*W. J. Phillipps del.*

Galaxias attenuatus (New Zealand Minnow).

While at Hokitika during September, 1920, whitebait were not running freely from the estuary up-stream, and the desire for rain was universal, for I was informed that after rain the river immediately rose in volume, and larger numbers of whitebait ascended. I then considered that larval shoals at sea would the more readily come in touch with water of less density off the river-mouth, and make their way to the river; but the explanation may be that the larger volume spreads over the mud-flats and releases the young fish, which make their way up-stream. Ova taken from females and placed in water by me have been found to be demersal.

The possibility of increasing the run of whitebait in our rivers by means of judicious legislation makes the study of the minnow of great commercial importance; but much remains yet to be done in the way of securing first-hand information. *Galaxias attenuatus* is the only fish canned and exported from New Zealand as whitebait. The smelt, *Retropinna retropinna*, runs up-stream in October and November, at the end of the whitebait season; but the only shoals I have seen kept well out in the current, and did not mix with the young minnows, which kept close to the bank. The larvae of the common bully, *Gobiomorphus gobioides*, apparently join in the spring migration up-stream, as I have taken the young among whitebait secured in August. This latter species is not considered palatable by those who have attempted to eat it.

During October and November, 1923, Mr. N. Welsh secured a number of larval *G. attenuatus* in a small stream at Boom Rock, north of Makara, on the west coast of the Wellington Province. These were retained with varying success in an aquarium in the Dominion Museum, and measured anything from 1 in. to 2 in. They were extremely quarrelsome, and appeared to injure each other rather severely in the confined space. Minute pieces of meat and small water-worms were eaten greedily. One fish invariably assumed command, its first act being to bite each of the others in turn ; and, if the ruler was removed, as was done several times in succession, another immediately took command and commenced to bite, even if only two were left in the aquarium. Under such conditions it is natural to assume that only one would survive. This is exactly what took place, and one individual lived until the 1st April, at which time it would have migrated to brackish water in its natural habitat.

In swimming, the young fish elevates its body anteriorly until it appears to move forward at an angle of 45° to the plane of the bottom. It has a remarkable power of clinging to upright objects, and can jump over 6 ft. in a direct line. This forced me to keep the top of the aquarium covered, and even then the smallest fish would climb 6 in. out of the water up the vertical glass sides.

During January, 1922, I had the opportunity of examining young, half-grown, and adult fish in the Wairau River, Blenheim. The adults continually rose to the surface to take a small white insect, *Syrphus* sp., which hovered near the water. The young, however, were rarely observed to rise, but spent most of their time foraging among dead and growing plants in the river, where, doubtless, they secured quantities of insect larvae, diatoms, and infusorians, all of which were found later to be fairly common at the point of observation. Microscopical examination of the stomach-contents of Museum adult specimens revealed the remains of copepods and other crustaceans.

BONES OF THE MOA IN VOLCANIC BEDS AT AUCKLAND.

By J. A. BARTRUM, Auckland University College.

ON the 5th April of this year workmen engaged upon excavating a site for an extension of the Auckland City Tramways workshops at Epsom discovered several moa-bones under interesting circumstances. I am greatly indebted to Messrs. Harris and C. Allen, of the engineering staff of the tramways, for their kindness in informing me of the discovery, and giving me particulars about the situation of the bones.

The geological section is shown in the illustration. The lowest rock exposed is a basalt, which is presumably part of one of the earlier flows from One Tree Hill volcano, near-by on the east. This forms the irregular floor of the excavation. Above it there is an old black soil, the depth of which is somewhat variable owing to intermixture with loose blocks of basalt, but which averages about 1 ft. This is covered by moderately fine

volcanic tuff in well-laminated layers. The lowest foot or two of this tuff contain abundant cavities, generally more or less horizontal, which represent the casts of tree-stems which have disappeared by decay, and very plentiful impressions of leaves resembling those of *Podocarpus totara*. One large nearly horizontal cast of a tree-trunk can be recognized in the central portion of the illustration, about 1 ft. above the surface of the old soil.

After about 7 ft. of this volcanic tuff had been deposited there was evidently a moderately long pause in the eruptions, and the superficial layers of tuff had time to break down into a thin soil, on which grew vegetation, now represented by numerous casts of rootlets in the ancient soil and subsoil. Volcanic activity, however, later broke out afresh, and another deposit of fine ash is represented by about 2 ft. of tuff immediately underlying the modern soil.

The bones were discovered near the upper surface of the old soil immediately above the basement of basalt, at the spot shown in the figure by the head of the pick. When the eruptions of fine debris began, these bones were only half-buried in the soil, and their upper portions were therefore embedded in the volcanic tuff. This latter material, unfortunately, is relatively pervious, so that the state of preservation of the fossils is not good. In addition, considerable damage was done by the workmen before the interest of the discovery was realized, with the result that the remains available for examination are fragmentary. The upper portions of the femur and tibio-tarsus, the fibula, several post-sacral vertebrae, and a portion of the sacrum are the chief of the more easily recognizable bones.

Mr. Griffin, of the Auckland Institute Museum, where these bones are now lodged, has been good enough to compare them with others in the Museum collections, and concurs with me in the opinion that they represent some fairly large species of moa.

Though the discovery does not add any fresh facts to those we already possess concerning the history of the moa, it furnishes an interesting addition to the fossil record of that bird.

THE ROOT-NODULES OF NEW ZEALAND PINES.

By J. S. YEATES, M.Sc., National Research Scholar, Victoria University College.

WITH the exception of two species of *Libocedrus*, all the New Zealand pines have on their roots numerous lateral swellings, more or less spherical in shape, and of a size fairly regular in any one species, but varying considerably in different species. Such "nodules" or "tubercles" are not confined to our New Zealand taxads, and have been the cause of some dissension in other countries.

Shibata, a Japanese worker, has twice published on the subject, and holds the view that the nodules are filled with fungus of a mycorhizal nature. Miss Spratt, working in England on material of totara (*Podocarpus totara*) and other taxads, claims that the nodules are caused and occupied by nitrogen-fixing bacteria similar to those of legume-nodules. More recently, Dr. McLuckie, of Sydney, has obtained for some Australian taxads results agreeing with those of Miss Spratt. Professor E. H. Wilson, of Harvard, who recently visited New Zealand, writes as follows (see Cockayne, 1): "The tubercles are analogous with those on leguminous plants, and in all probability the bacteria break up the raw humic acids and convert them into readily available salts." In the course of the present work nodules have been examined from all the New Zealand members of the group, with the exception of two or three species, and also from several species of the Araucarineae—the monkey-puzzles—allied to our kauri (*Agathus australis*). Save for a mention by Cockayne (2) on the kauri, the nodules of this tribe (Araucarineae) seem as yet to have been overlooked.

Structurally the nodules are lateral roots, the apical growth of which has been checked. In some trees — the kauri, the Norfolk Island pine (*Araucaria excelsa*)—there are found all stages between perfect nodules and ordinary roots. The intermediate forms are roots more or less checked in apical growth, but still plainly roots. Each year such a root grows a new portion, which bursts through the end of the previous year's growth, and so the root comes to have a jointed appearance. The English yew (*Taxus baccata*) has roots of this kind.

Some nodules, such as those of kauri or of white-pine (*Podocarpus dacrydioides*), behave in a similar manner, a young nodule being produced each year at the apex of the old one (fig. 3). In other cases, where the restriction of apical growth has been carried further, the young nodules are produced each year completely inside the old ones (*P. totara*, &c.).

Internally the nodules consist of a large-celled cortex surrounding the short vascular strand which connects with the vascular tissue of the main root. The large cortical cells of the nodules have in many species (especially of *Podocarpus*) peculiar bar-like and anastomosing thickenings on their walls. These thickenings are very similar to those found in the xerophytic bog-moss, *Sphagnum*, and the function of the tissues bearing them is no doubt the same in each case—the absorption and storage of water. It has seemed to me that if this be the function of the tissue in the nodules, then leaf-structure, the main index of a xerophytic state, should exhibit differences in the various species, corresponding to the volume of such water-tissue on the roots.

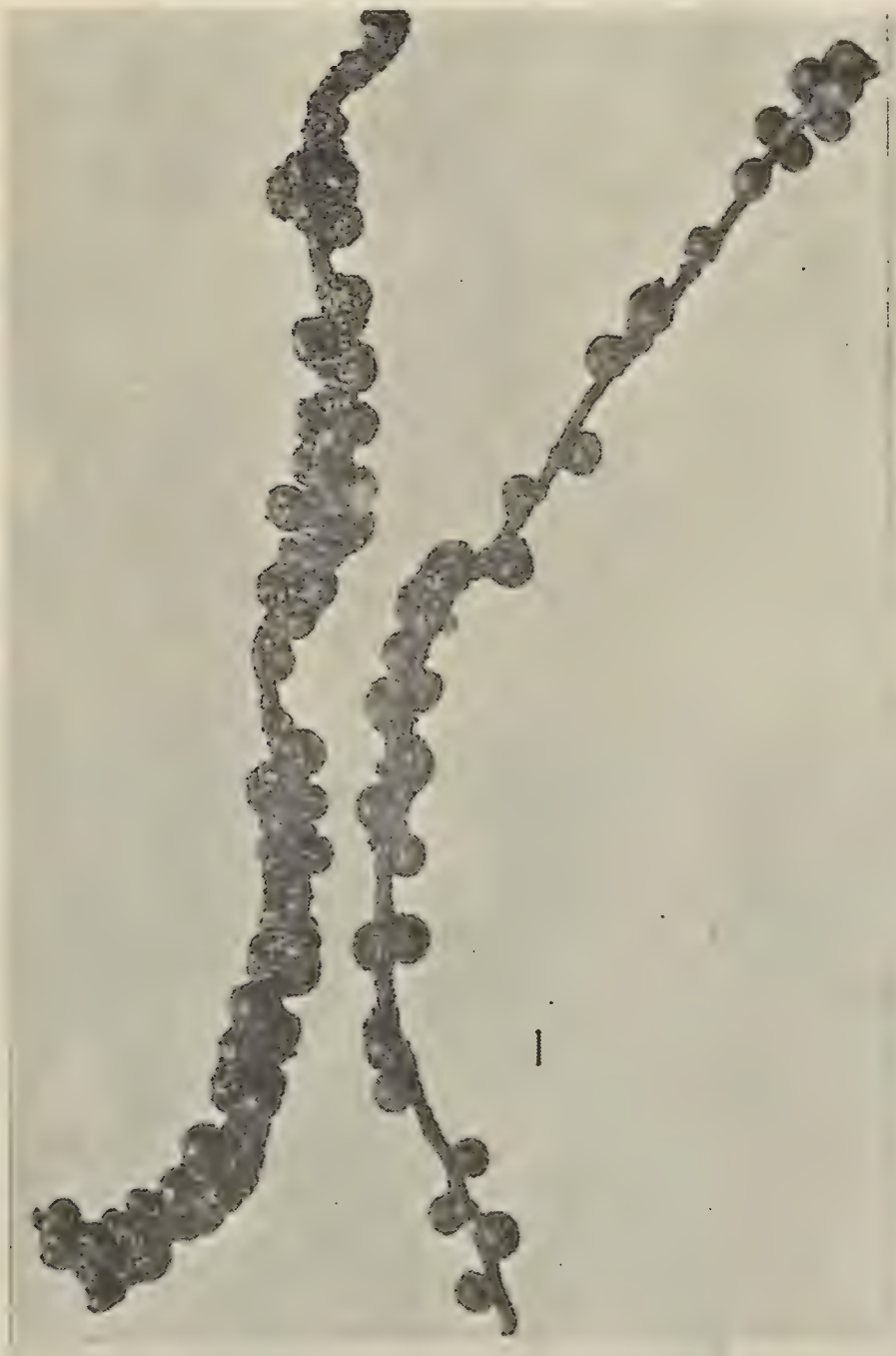

FIG. 1.—Root-nodules of miro (*Podocarpus ferrugineus*): × 2·35.
FIG. 2.—Juvenile leaves of miro (*Podocarpus ferrugineus*): natural size.
FIG. 3.—Root-nodules of white-pine (*Podocarpus dacrydioides*): × 2·35.
FIG. 4.—Juvenile (larger) and adult leaves of white-pine (*Podocarpus dacrydioides*): natural size.

This expectation is fully borne out, for amongst our Dacrydia and Podocarpi the size of the juvenile leaf in any particular species is roughly proportional to the size of the root-nodules in that species (compare sizes in figs. 3 and 4 with sizes in figs. 1 and 2). It cannot be expected that such a rule should hold strictly, for although leaf-size is an important factor, yet other factors, such as leaf-thickness and protection of stomata, play an important part in the water economy of the plant.

It must be noted that the above relationship holds for the leaves of juvenile forms alone. Many of the taxads have much smaller leaves as adults than as juveniles. It is found that, as a whole, the species in which water-tissue is least developed in the nodules are the species in which the change from juvenile to adult leaf is most striking. In other words, absence of sufficient water-tissue on their roots has compelled these species to reduce their leaf-surface and so to economize their water-supply (*D. biforme*, *D. Colensoi*).

Such a possible explanation of the juvenile forms of New Zealand pines suggested at once its application to gymnosperms as a whole. The change from large juvenile leaves to small adult leaves is common in all tribes of conifers except the Abietineae, and in the Abietineae alone of these tribes is endotrophic mycorhiza lacking. The distribution of endotrophic mycorhiza and of juvenile forms in the gymnosperms thus seem to coincide. It seems possible that the change to smaller leaves has been necessitated by a process of root-reduction carried to such lengths that the lateral roots are no longer present even as nodules. Such a process of reduction would be merely a continuation of the process which has led to the formation of the nodules as we know them. Moreover, the presence of endotrophic mycorhiza is widely recognized as a cause of root-reduction and consequent leaf-reduction (Bower).

Investigation of species of Taxadineae and Cupressineae—*Cunninghamia* in the former, *Libocedrus* and *Cupressus* in the latter—shows that the mycorhizal fungus agrees in all respects with that of the taxads. Young trees of *Libocedrus Bidwillii* occasionally bear " dwarf roots " corresponding in all essentials to the nodules mentioned above. The sparingly branched nature of the roots of such trees as *Libocedrus* and *Cupressus* also suggests the loss of many lateral roots.

As for the organism which occupies the nodules, there can be no doubt that fungus is present in every species so far examined. That bacteria are present under some conditions is quite probable. Out of several hundreds of nodules examined, representing about twenty species and a range of territory from Hokitika to Ruapehu, only one nodule could definitely be said to contain bacteria similar to those figured by Spratt and McLuckie. In the vast majority of cases a non-septate fungus was present, being easily distinguished from a bacterial zoogloea by its definite hyphae and by peculiar nucleated vesicles which may be degenerate sexual organs. Similar vesicles have been observed in a considerable number of plants where fungus is undoubtedly the symbiont. Amongst these are the prothalli of *Lycopodium* and of *Tmesipteris*.

The part played by the nodules in the physiology of the plant is two-fold :—

(1.) Water-storage : As stated above, there is good reason to suppose that the nodules, especially in *Podocarpus*, act as tissues for water-storage. The most striking suggestion I have seen in this connection lies in the dense matting of nodules around trees of *P. ferrugineus* and *P. Hallii*. In wet

rain forest, such as occurs to the north of Ohakune, the roots of these trees occupy a large percentage of the volume of the top soil. In most cases the nodules are directly exposed to the damp atmosphere of the forest. Moreover, they are found to ascend the trunks of other trees and of ferns to a height of 4 ft. or 5 ft., provided a suitable covering of moss or bark be present. In one case a springy cushion about 2 ft. across and perhaps 9 in. deep was composed chiefly of nodules of *P. Hallii*.

(2.) The symbiotic relationship with the fungus: In the outer region of the nodule the fungus is in a normal state, but in the rest of the nodule it undergoes a process of decomposition or digestion by the cells of the host. An intermediate stage in the digestion of the fungus is often the production of irregular, densely-staining masses in the cell. Similar bodies are found in the mycorhizal portions of other plants.

Although the fungus during its growth no doubt receives a certain amount of nutriment from the host, yet it seems probable that a certain amount of organic material is also obtained from the soil—at least in places where the soil is of an organic nature, as on the average rain-forest floor. The prothallus of *Tmesipteris* is of interest in this connection. Chlorophyll, as Dr. Holloway has shown, is completely absent from it, yet in virtue of the mycorhiza—similar to that of taxad nodules—it is able to grow and to produce a young sporophyte at the expense of the organic substratum.

Our taxads show in most cases a full green colour, so that they have two methods of securing organic material—through the leaves and by means of the fungus in their nodules. The brown-leafed, divaricating stage of the matai (*Podocarpus spicatus*) is a close approach to the chlorophyll-less state of many advanced saprophytic phanerogams. Moreover, the nodules of such a tree of *P. spicatus* contain what is perhaps the most dense mycorhiza found in any species so far examined.

In conclusion, it must be pointed out how highly adapted is the root-system of our taxads to rain-forest conditions. The wide-spreading roots place the nodules in the best possible manner for absorption and storage of water, and at the same time, being localized in the organic layer of soil, have the best possible opportunities for saprophytism. Only under rain-forest conditions is such a root-system possible.

It is hoped to publish shortly a fuller account of these nodules, and evidence will be brought forward in support of the above views. In the meantime I wish to thank Professor H. B. Kirk for his invaluable aid and advice, also for literature and material; Dr. Cockayne, F.R.S.; Professor C. Chilton, D.Sc.; Rev. J. E. Holloway, D.Sc.; Captain MacIntosh Ellis, Director of the State Forest Service; Mr. G. H. Cunningham, B.Sc., Government Mycologist; and Mr. V. Davies, of New Plymouth.

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THE CULTIVATION OF NEW ZEALAND PLANTS.

A PLEA FOR A NATIONAL BOTANICAL GARDEN.

By B. C. ASTON, F.I.C., F.N.Z.Inst.

DR. L. COCKAYNE has broken entirely new ground in his usual original and interesting way by the publication of a compact volume dealing with the cultivation of New Zealand plants.* This little work is one which should be on the bookshelf of every New Zealand home, for in it the distinguished author has focused to a fine point the experience of half a lifetime in field, garden, and study. The book has everything in its favour—an exceptionally interesting theme, a reasonable price, and an author who probably knows more about the distribution of New Zealand plants than any other living man, having made the subject his sole study for the past thirty-five years. Needless to say, Dr. Cockayne has succeeded well with his subject. But one feels that this book is written with an object—to reach the great body of men and women who love their gardens, and to make them realize the beauty of New Zealand plants—otherwise the author could easily have written a book four times the size and proportionally more costly. Nevertheless the next edition must be larger and more comprehensive, and deal with the plants which are more difficult to grow, and with the special kinds of gardening at present becoming adopted by persons of any individuality who desire their home surroundings to rise above the commonplace. Such are those who aspire to cherish a real rock, water, bog, or wild garden. It is mainly in these special forms of gardening that the writer of this paper desires to offer some remarks, to call attention to a few choice plants which have escaped notice, and to submit notes on plants difficult to grow. These notes are the result of his personal observation in cultivating native plants during the past thirty-five years.

TREES AND SHRUBS.

Among those which may be grown successfully in the North Island especially are *Litsaea calicaris*, which makes an extremely handsome shrub in the young stage, unlike anything else in the flora. The timber of the mature tree is valuable, and the growth-form is characteristic. Large quantities of seedling plants are obtainable in the forest near Rotorua. The writer has found that *Cordyline indivisa* may be grown in full sunlight and unprotected from the wind, provided the soil is very deep and well drained. *Carmichaelia* plants usually strike readily from cuttings—a useful fact which is not generally known. The writer considers *Ixerba brexioides* most difficult to cultivate, and a very slow-growing tree. Species of *Clematis* are best lifted as old plants. Clumps of old roots make much quicker growth, and save one waiting some years longer for the plants to flower. Potts states that *C. indivisa* was covered with a fine show of blossom in the fifth year from seed. *Drimys axillaris* and *D. colorata* are both shrubs of very slow growth. *Pittosporum cornifolium*, although naturally an epiphyte on rocks or trees, grows well in soil, and may be raised from seeds or cultivated from young plants

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* L. COCKAYNE, F.R.S., *The Cultivation of New Zealand Plants* (Whitcombe and Tombs, Limited), 1924.

collected from the forest. The orange-yellow valves of the fruit are very attractive and unusual. It is a plant for the shady side of the rock-garden or as a border-shrub. *Halorrhagis erecta* is a subshrub of low but copious growth, and, having handsome foliage, is suitable for borders of shrubberies. *Discaria toumatou* is not a handsome plant, but the flowers are powerfully fragrant, and in nature it forms an admirable support for *Clematis marata*, and possibly other small species of *Clematis*. On account of its distinctive appearance it should find a place in collections of native plants. *Griselinia littoralis* is excellent as a hedge-plant; and *Corynocarpus laevigata* makes a fine tall boundary-hedge, and may be freely trimmed.

ROCK-GARDENS.

For rock-gardens the epiphytes or perching-plants must be given a place. Such beautiful orchids as the three species of *Earina (E. suaveolens, E. mucronata*, and *E. aestivalis)* and the bushy *Dendrobium Cunninghamii* can all be grown on shady rockwork, or on old stumps which it is desired to beautify. *Sarcochilus adversus* and the two species of *Bulbophyllum* are also interesting epiphytes, though lacking conspicuous flowers. *Scleranthus biflorus* forms large yellowish-green pincushion-like clumps of mossy growth on rockwork with remarkable little trouble on the part of the gardener, and might be extremely useful as a border-plant. *Plantago spathulata* is a plant of rosette form, but with large leaves of an unusual colour, form, and hairiness. *Eryngium vesiculosum* has pretty prickly leaves, but the plant needs controlling. Other littoral plants with good foliage but poor flowers are *Lepidium oleraceum* (an historical plant) and *Sonchus asper* var. *littoralis*, which forms large, glaucous, succulent rosettes in any rock-crevice, and reproduces itself abundantly in cultivation. *Lobelia anceps*, though the flowers are small, forms useful masses of green growth, with tiny bluish flowers, on damp rocks. *Stackhousia minima* should be grown on dry ground, for its fragrance. *Rhagodia nutans* is one of the easiest plants to grow, its pink fruit being conspicuous in season. It quickly forms masses of trailing glaucous growth on any dry bank. *Mesembryanthemum aequilaterale* is remarkably easy and very quick to grow, and is a finer plant than *M. australe*. *Euphorbia glauca* is a distinctive plant of a very aggressive growth, and does well on any rocky bank or odd corner, however steep, where it can be controlled. *Craspedia* in its many species or varieties is a handsome rosette plant, with viscid, scented leaves, and should certainly be grown on the native rock-garden. *Elatostema rugosum* is one of the most charming foliage plants in the flora. It is easily grown in shade wherever water trickles from a spring, and the plant may be collected as far south as Levin, although found in greater abundance on the wet banks of the Wanganui River. Mr. E. Atkinson has naturalized it admirably in his bush at Lowry Bay. *Veronica-plebeia* is a good rock-plant.

CHOICE DIFFICULT PLANTS.

Of bog and water gardens the writer has no experience, but certain New Zealand plants should be experimented with, notably the giant *Prasophyllum patens* — 3 ft. high, and sweet-scented, with conspicuous flowers—certainly one of the rarest of New Zealand plants. Some of the *Thelymitra* species thrive in bogs, and have the most beautiful blue flowers. Under damp, shady banks the *Corysanthes*, interesting for their remarkable purple flowers with filamentous perianth-segments, will always attract attention. An attempt to grow *Astelia linearis*, with its conspicuous large

red fruit, should also be made. A constant source of regret to all those who know the rare and beautiful plants of New Zealand is the difficulty of growing some of them. The late firm of George Matthews and Son, of Dunedin (established 1850), were very successful in growing quantities of such plants as *Ranunculus Lyallii* by diligently preparing a deep well-drained bed of soil obtained from a near-by mountain. This firm also grew for many years the rarer composite shrubs of the southern islands. In the firm's catalogue which was published about forty-five years ago such plants as *Olearia angustifolia, O. Traillii, Stilbocarpa polaris,* and *Senecio Huntii,* which grow to perfection in salty, peaty sands, are listed, and were grown by this firm at Mornington, Dunedin, and one part of the treatment was to dose them with common salt occasionally. The glorious plants of the Auckland Islands would seem to be particularly difficult to grow, judging by the fact that such plants as *Veronica Benthami,* the finest of the veronicas, is never met with in cultivation, although Sir George Fenwick tells us that arrangements have been made to try to grow it at Wetherstones (Messrs. Hart and Darton's veronica-garden near Lawrence, Central Otago). The other outstanding plants of the salty peat lands of the southern islands most worthy, but never cultivated, are here given, with Dr. Cockayne's opinion of each one in inverted commas. It may be added that these wonderful plants all grow in the same kind of soil and situation, the salt peaty uplands of the Lord Auckland Islands, the actual habitat being described as "peat sodden with water, very little sunshine, almost daily rain, temperature low all the year round, but rarely more than one or two degrees of frost."

Celmisia vernicosa—"one of the gems of the New Zealand flora."
Gentiana cerina—"easily the queen of the gentians."
Myosotis capitata—"undoubtedly one of the most lovely plants of the flora."
Pleurophyllum speciosum—"glorious, gigantic."
Chrysobactron Rossii—"gorgeous."

Surely it is worth while trying to grow these wonders of the floral world in some more accessible place than what has been called the "New Zealand lone lands."

To come to some beautiful plants nearer home, the gentians, the writer has grown *Gentiana saxosa,* a littoral species, easily enough, and it is listed for sale in Matthews's catalogue, so that it is probably not difficult to grow; but, coming to the handsome mountain-gentians, Mr. W. A. Thomson, of Half-way Bush, Dunedin, who has had twenty-five years' experience in growing New Zealand plants, kindly supplies the following notes. He finds a slope which is artificially constructed in continuation with an existing slope the best situation to grow gentians. A slope with a southerly aspect needs the sun all day; one with a northerly aspect for only half a day. The artificial slope should be formed of materials built up in graded sizes from boulders of various sizes to gravel—the coarest, the boulders, at the bottom, the finest, gravel, at the top. On the surface is laid the bedding-material of peat, mixed with grit composed of broken-down slate, fine quarry screenings, mica schist, fine sea-sand (well washed to extract the salt), or others. The peat is allowed to dry and is broken fine, and then mixes well with the grit. The more sunlight or heat which falls on the slope the more peat will be required; with less heat more sand may be added. Mr. Thomson supports Dr. Cockayne's suggestion that gentians are best grown from seed, but this must not be allowed to dry, and is best collected on wet moss in a

tin. Young plants taken from the mountain do well, but the soil must not be shaken from the roots, and the plants must only be exposed to the sun's rays gradually in the new environment.

Mr. Thomson's experience with *Myosotis* is worth recounting. Species of *Myosotis* are best raised from seed planted where the mature plant is intended to grow, the seed to be collected in the same way as that of gentians. Those species which grow on shingle or on cliff-faces will do well in grit without any peat, sheltered by overhanging rocks. Such species as *Myosotis macrantha*, *M. Monroi*, should have their roots in the slope itself, and get the sun for half the day. The purely peat-loving species, such as *M. capitata*, should be grown in peat alone, and are then easy to cultivate. Some few grow in the very wet ground and require the water moving through the roots on the wettest part of the slope. Lastly, those species such as *M. Forsteri* like an eminence in a damp spot, not necessarily peaty, and with not too much sun. Mr. Thomson finds the greatest enemy of the *Myosotis* plants is mildew, which is combated by dusting with sulphur. The mildew is almost a sure sign of unsuitability of position.

The *Celmisia* genus is easy of cultivation in most instances. *Celmisia Thomsoni* is difficult, but seed scattered broadcast on a wet bank with little sun do well. Some *Celmisias* will last for thirty years, and twenty years is of common occurrence. Finally, Mr. Thomson has grown *Pleurophyllum*, and states that they will live for fifteen years if they have abundance of water. They do not flower regularly, but come well from seed, and he thinks they might succeed well in the south-west mountain-tops of the South Island.

The scattered distribution of the finest plants of New Zealand prompts the question whether it would not be possible to grow them all in some well-selected site to form the nucleus of a national botanical garden. Here an endeavour might be made to bring together the noble subantarctic element of our flora already mentioned, the East Cape and the Marlborough endemic plants, the Stewart and Chatham Islands tree composites, and all the beautiful alpinic plants of both Islands. Provided some such mountain as Mount Egmont were chosen, stretching from sea-level to beyond subalpine heights, the writer sees no reason why all the native plants could not be grown successfully. Already there are national parks at Mount Egmont, Mount Ruapehu, and in the Fiordland, with custodians, rangers, and caretakers. There are sanctuaries, and caretakers for them. Could not a beginning be made on one of these sites, and a national aboretum or botanical garden established under conditions which would assure its perpetuity ? The fault of private or even municipal gardens is that, when collections of New Zealand plants are established, the life of the collection is synchronous with the life of the collector. Private collections are obviously fated to untimely ends, and public collections are subject to like fate owing to change of management. It seems that the foundation of such an institution as here proposed would be a very fitting commemoration of not only the life labours of those eminent botanists who have gone, but of those who are still with us.

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THE MOUNTAINS OF THE MOON.

By A. C. GIFFORD, Associate in Astronomy, Hector Observatory.

POPULAR interest in astronomy is focused rather unduly on the planet Mars. Venus, the sister planet to the earth, is much nearer to us, and is interesting on account of its great brilliance, its rapid motion, and its recurring changes of phase. Mercury enjoys most of the same advantages, although smaller than Mars and not so well placed for observation. Saturn, with its ten moons and its wonderful system of rings, is incomparably more beautiful. Jupiter, by his enormous size, much more than makes up for his greater distance; and the phenomena of his satellites afford a never-failing source of interest to the observer. Compared with Saturn, Jupiter, or even Venus, Mars is a disappointing object when seen through a small telescope. In spite of these facts, Mars is spoken of in newspapers and magazines ten times as often as any other planet. This is due, no doubt, to the work of Schiaparelli and Lowell having caught the popular imagination; whilst there is no contemporary writer who can arouse a wide interest in all astronomical questions, as R. A. Proctor did nearly half a century ago.

Now, it is well known that once in each period of fifteen or seventeen years Mars approaches unusually near to the Earth, owing to its opposition occurring at a time when, in their elliptic orbits, Mars is almost as near, and the earth nearly as far, as possible from the Sun. The opposition of Mars on the 22nd August, 1924, was an unusually favourable one for observation. Yet even on the occasion of that exceptionally near approach Mars was still about 145 times as far from us as the Moon is. If, then, choosing such an opportunity, we examine two objects of equal size, one on Mars and the other on the Moon, the image of the lunar object on the retina of the eye will excite an area much more than 20,000 times that excited by the image of the Martian one. How little, then, is it possible

to learn about the surface of Mars compared with what we can tell of that of the Moon! Not only, however, have volumes been written about the markings on Mars, but the keenest interest is taken in their interpretation. It is astonishing, therefore, that we have to confess that we do not understand the origin of any single one of the most prominent and most remarkable surface features of the Moon. Compared with Mars it is at our very doors, and its markings certainly require some explanation. The scarred face which it turns perpetually towards us is unique amongst all that we can see in the universe. There is nothing really like it on the surface of the Earth, and no other body is sufficiently near for us to tell whether it possesses any similar features.

It is not for want of study that the lunar geology remains a mystery. The topography of the Moon's surface is better known than that of some portions of the Earth. No other object has been so carefully scrutinized ever since the invention of the telescope, and the Moon is extremely favourably situated for our observation. Each portion of the visible disc undergoes a complete cycle of varying illumination every month, thus enabling a correct idea to be formed of the vertical relief as well as the horizontal configuration of all the details. There are no lunar clouds to obscure the view, and owing to the absence of twilight all shadows are sharp and distinct.

DESCRIPTION OF THE LUNAR SURFACE.

It is not necessary to give any minute description of the lunar surface, as excellent photographs have made its details familiar to all. Even with the naked eye it is evident that the surface is irregularly divided into lighter and darker portions, like a picture sketched in charcoal on a light circular background. The contrast between the light and the dark areas is exaggerated by photography. In these lunar markings all kinds of resemblances may be traced to faces and other terrestrial forms. The extraordinary character of the whole lunar surface is not revealed until a telescope is used. The greater portion of the visible disc, but more especially the lighter part, is then seen to be covered with innumerable circular structures of a characteristic and remarkable form, scattered apparently quite indiscriminately, and varying in size from the smallest pits visible under the highest power up to vast ringed plains more than a hundred miles in diameter. These rings are stilled called "craters," and the roughly circular dark areas are still known as "seas," although the volcanic origin of the former is improbable, and although there is no evidence in the latter of the presence, or even of the past action, of water. The surface of the seas appears to be very much smoother than that of the light areas; it is much less broken by craters, and it generally lies at a distinctly lower level than its surroundings. Not only is each sea bounded more or less completely by higher ground, but the immediate margin is often fringed by curved ranges of lofty mountains, giving the impression that it is really a ringed plain on a grander scale. The seas vary in size from the great ill-defined Oceanum Procellarum to some not much exceeding the largest craters—with which, indeed, they have much in common. Other interesting features on the Moon include the well-known but unexplained systems of rays from Tycho, Copernicus, Kepler, and Aristarchus, multitudes of cracks and rills, and the isolated mountain-peaks. The craters, of which about thirty thousand have been mapped, are, however, undoubtedly the most characteristic of all lunar forms. If their origin

can be determined, it seems probable that a flood of light will immediately be thrown upon other dark parts of lunar geological history.

UNSOLVED PROBLEMS.

Considering the wonderful advances that have been made in recent years in all branches of astronomy, considering also the nearness of the Moon to us, and the consequent clearness of its enigmatic features, which by their very strangeness seem to cry aloud for explanation, it is wonderful that their origin still remains so completely unexplained. This may appear too decided a statement of the case, but when we examine what has been written about the Moon we find that several of those who know most about it are the readiest to acknowledge that they are unable to suggest any theory that accounts satisfactorily for lunar forms. As an instance of this, in the *Adolfo Stahl Lectures in Astronomy*, 1919, there is printed in full an extremely interesting lecture on the Moon by Professor R. G. Aitken, of the Lick Observatory. After describing the features of the lunar surface, Dr. Aitken says: "Now, you will ask, as does every intelligent visitor to the Lick Observatory after seeing the Moon through the telescope, 'What caused the craters?' I wish I could tell you. But if I am to be perfectly honest I shall be obliged to confess that I do not really know. The question of the origin of the various lunar surface features is one on which astronomers are still in doubt." Later on he says: "Of the many theories that have been proposed at one time or another we need here examine only the two which at the present time command the serious attention of astronomers—the classic 'volcanic' theory and the 'meteoric' theory . . . Probably the term 'craters,' which was early given to these formations because of their superficial aspect, has been the source of unconscious prejudice in many minds in favour of the volcanic theory; just as the unfortunate translation of Schiaparelli's Italian term *canali* by our English 'canals' has unquestionably been a powerful factor in creating the widespread belief in the artificial origin of these well-known markings on Mars. Be that as it may, it is safe to say that a majority of astronomers favour the volcanic theory, or, to use broader terms, the theory that all the observed configurations of the lunar landscape are the result of the action of forces originating in or on the Moon itself."

Similarly, H. S. Jones, in *General Astronomy*, 1923, states: "The causes of the origin of the craters must therefore be regarded as still an open question: no theory yet advanced can account for their existence on the Moon and not on the Earth . . . Equally puzzling are the systems of bright streaks radiating from Tycho and a few other craters. These cast no shadows, and are therefore neither elevations nor depressions. They pass on in straight lines over craters, rills, or whatever object lies in their track. No satisfactory explanation of them has yet been given."

Philip Fauth, in *The Moon in Modern Astronomy*, says: "But the ultimate aim of all these efforts, the explanation of the processes that have left these traces on the surface of our satellite, has not yet been attained."

F. R. Moulton, in *An Introduction to Astronomy*, says: "The explanation of the craters is by no means easy, and universal agreement has not yet been reached."

Finally, Bruno H. Burgel, in *Astronomy for All*, says: "These circular formations, with or without a central cone, are to be seen everywhere.

How is it that all this has one and the same pattern? No definite answer can be given. . . . We may as well confess that the origin of this lunar phenomenon still baffles us."

EXPLANATIONS SUGGESTED.

Robert Hooke, in 1667, described experiments he had made, and suggested that the craters on the moon had an origin similar to that of the pits which he observed in boiling alabaster.

Sir John Herschel accepted the volcanic theory, and it has since been adopted, with little or no examination, in numbers of text-books on Astronomy.

Nasmyth and Carpenter made a very thorough and careful study of the lunar surface and elaborated the theory, which they published in 1874, that the eruptions forming the craters were caused by the expansion of the material beneath the crust consequent on its solidification.

H. Ebert and Paul Fuchs considered that the circular form of the craters was due to the alternate extrusion and retraction of a suitable magma through an orifice in the crust.

Philip Fauth rejects both the volcanic and the meteoric hypotheses, and maintains that the Moon is covered with a thick layer of ice. He does not, however, make it clear how he believes the vast rings to have been produced.

The meteoric hypothesis was suggested by Proctor in 1873 in his book *The Moon*. He showed that the nebular hypothesis of Laplace failed to account for many of the peculiarities of the solar system, which appeared to be more satisfactorily explained by regarding it as formed by the gathering-in from outer space of materials once widely scattered. He pictured the Sun maintaining its fires under the impact and collisions of bodies so collected, and the Moon whilst still in a plastic condition receiving the impress of the meteoric rain. He hesitated about applying this suggestion to the larger craters, but pointed out that no plausible theory had been advanced to explain these remarkable formations. In the edition of his work published in 1878 all reference to this hypothesis was omitted.

Meydenbaur (1882) believed the whole surface of the Moon to be covered with a thick mantle of cosmic dust, and the lunar craters to have been formed by aggregates of similar dust falling upon it. The larger craters and maria he attributed to the impacts of solid masses of sulphur or phosphorus, which he considered were originally satellites of the Earth.

Würdemann suggested that the rays from Tycho and other craters were caused by meteorites striking the Moon with great force and spattering some whitish matter in various directions.

Dr. G. K. Gilbert, in 1892, developed a more complete meteoric theory. He pointed out very clearly the essential differences between lunar ringed plains and terrestrial volcanoes. He compared the lunar forms with those made by dropping pebbles into pasty mud, or firing projectiles into plastic materials. He calculated that the impact of a body striking the Moon's surface with a parabolic velocity would raise the temperature to 3500° F. or higher. This would melt much of the rock and account for the level floors of some of the craters. To account for the roundness of the formations he assumed that the meteorites were originally a ring of moonlets revolving round the Earth.

T. J. J. See, in his *Researches into the Evolution of Stellar Systems*, 1910, maintains that the so-called craters are simply satellite indentations in a

surface of loose and largely uncemented cosmical dust and fragmentary rock and not volcanic at all. He pictures a satellite fifty miles in diameter colliding with the Moon, sinking down into the uncompacted material, flattening and spreading out at the base, and thus making a broad saucer shaped depression three times its original diameter, the peak in the centre being a remnant of the satellite itself.

In his great work *A comparison of the features of the Earth and the Moon* N. S. Shaler examines carefully the volcanic and meteoric theories, and comes to a surprising conclusion. Several previous writers had been willing to accept a meteoric origin for the small pits, whilst refusing to believe it possible for impact to produce the vast ringed plains. Shaler, on the other hand, discards the meteoric hypothesis as an explanation of the origin of craters, but accepts it in the case of the still more gigantic seas.

NARROWING THE QUESTION AT ISSUE.

Practically all modern writers agree that it is unnecessary to consider more than two of the theories that have been advanced, and the two almost universally selected are the classical volcanic theory and the more recent meteoric hypothesis. The question to be answered is whether all the lunar forms were produced entirely by internal forces, or whether they are due in any way to action from without. If this question were to be decided by an appeal to authority there is no doubt what the verdict would be. It is easy to name more than two dozen writers who definitely accept the volcanic theory. Those who uphold any form of meteoric hypothesis can be counted on the fingers of one hand. A few others, from most of whom we have already quoted a sentence or two, reserve their decision. If, instead of counting votes, we weigh evidence, we find that, in the case of each of these theories, all serious criticism is destructive. Neither the volcanic theory, nor the meteoric as hitherto presented, can stand the ordeal.

In spite of its wide acceptance, there does not appear to be much—beyond a slight superficial resemblance between lunar rings and certain terrestrial craters—that can be said in favour of the volcanic theory. The early use of the word " crater " in describing lunar forms seems to have prejudiced many writers so strongly in favour of vulcanism that they accept the theory without considering any arguments for or against it. Some speak scornfully of other views. For example, Charles Lane Poor, in 1908, in *The Solar System*, says : " Although the volcanic origin of the lunar craters is almost self-evident, yet other theories have been advanced. Proctor suggested a meteoric origin ; the craters being the holes left by meteors falling upon a yet plastic surface. This and other equally far-fetched theories have received little or no support, and the volcanic character of the lunar mountains is practically established." With regard to the rays, however, even he acknowledges that no satisfactory and universally accepted explanation has yet been given.

OBJECTIONS TO THE VOLCANIC THEORY.

It is easy to enumerate facts which tell against the volcanic theory. Lunar craters are so numerous and of such vast dimensions that there is not room for them all on the entire surface. They overlap or obliterate one another. We cannot imagine that, at any stage of its evolution, the moon required such a multitude of blowholes.

There are no terrestrial forms that resemble at all closely the lunar ringed plains. Gilbert drew up an impressive list of contrasts between lunar craters and those of the volcanoes on the Earth. Here are a few: "Ninety-nine times in a hundred the bottom of a lunar crater lies lower than the outer plain; ninety-nine times in a hundred the bottom of a Vesuvian crater (taken as a type of terrestrial volcano) lies higher than the outer plain. . . . The lunar crater is sunk in the lunar plain; the Vesuvian crater is perched on a mountain-top. . . . If the Vesuvian crater has a central hill, that hill bears a crater at its summit and is a miniature reproduction of the outer cone; the central hill of a lunar crater is entire, and is distinct in topographic character from the circling rim. The inner cone of a Vesuvian volcano may rise far higher than the outer; the central hill of a lunar crater never rises to the height of the rim and rarely to the level of the outer plain. The smooth inner plain characteristic of so many lunar craters is either rare or unknown in craters of the Vesuvian type."

There is no evident law of distribution of lunar craters: they seem to be scattered indiscriminately. Volcanic action on the Earth appears to take place along lines of weakness or fracture. In some cases a number of small pits on the Moon are associated with a rill. But here the formation of the pits appears to have caused the fracture, rather than the fracture to have prepared the way for the pits.

The universal circularity of form in structures ranging from a fraction of a mile to a hundred and fifty miles in diameter is hard to explain from the volcanic point of view.

Terrestrial volcanic outbursts appear to be due to imprisoned steam, and volcanoes are limited to regions within three hundred miles of the sea. The absence of water from the Moon makes it difficult to account for the presence of vapour in sufficient quantity to produce eruptions capable of forming vast craters.

There is little or no evidence of lava-flows connected with lunar rings. The material of the surrounding walls and peaks is generally insufficient to fill the crater-bowls. Many lunar craters are found on the mountain-rims of others in positions in which volcanic craters could not be expected to occur.

The lunar seas are roughly circular in shape. The lunar mountain-ranges are portions of the curved rims of the seas. Any explanation to be satisfying should account for seas and mountain-ranges as well as for the craters. The volcanic theory cannot do so. But is the meteoric theory any more successful?

OBJECTIONS TO THE METEORIC HYPOTHESIS.

In nearly every book in which the meteoric hypothesis is mentioned three objections are urged against it, and these are considered absolutely fatal to it. They are—

(i.) To produce the lunar forms the meteoric bombardment must have been a terrific one, with innumerable meteors, many of them of vast dimensions.

(ii.) If lunar craters are due to meteoric impacts, craters of similar origin should be correspondingly large and numerous on the Earth, whereas the largest known, and the only one of any considerable size, is that in Arizona, which is only three-quarters of a mile in diameter and 600 ft. deep.

(iii.) Meteors colliding with the Moon would be certain to strike the surface obliquely, but the universally circular form of the lunar craters implies that, if they are due to impact, every meteor must have fallen vertically. Two markings only on the lunar disc are considered generally to suggest a glancing blow—viz., the Valley of the Alps and the valley near Rheita.

Other objections are mentioned by Shaler and Pickering, but these three are generally relied on, and are considered amply sufficient to refute the meteoric hypothesis. The facts are so certain. In any meteoric bombardment the majority of the impacts must have been oblique. The Earth accompanying the Moon through such a barrage could not possibly have escaped unscathed. The Moon's scarred face speaks eloquently of the magnitude and number of the missiles. Granting all these facts, objections (i) and (ii) are easily answered. Not so number (iii). It is strong enough by itself to lead to the rejection of the meteoric hypothesis, as it is usually presented. But in all discussions hitherto one all-important factor has been overlooked. The object of this paper is to ask for a reconsideration of the problem from a new point of view.

THE NEW METEORIC HYPOTHESIS.

The fact which has not been taken into account hitherto in considering the meteoric hypothesis is that a meteor, on striking the surface of the Moon, is converted, in a very small fraction of a second, into an explosive compared with which dynamite and T.N.T. are mild and harmless. Gilbert and See considered that meteorites would strike the surface of the Moon with a velocity of about one and a half miles a second, the parabolic velocity due to the Moon's attractive force. But it is known that the meteors which enter the Earth's atmosphere do so with velocities ranging from ten to forty-five miles a second. Those which collide with the Moon should have almost the same speed. The phenomena attending the encounter are, however, entirely different in the two cases. A meteorite which meets the rare terrestrial atmosphere, a hundred miles above the surface, with a speed of forty-five miles a second, loses nearly all its energy in a few seconds, and, being completely vaporized, disappears at a height of ten, twenty, or forty miles above the Earth's surface. If it is so massive as to escape being completely turned into vapour by the friction of the air, its speed is still further reduced while traversing the dense lower layers, and its strikes the Earth with so slight a momentum that it can penetrate only one or two yards into the ground, and may even fail to bury itself. Very different is the fate of a meteorite meeting the Moon, which has no protective envelope of air—or, if any, one so rare that its density does not exceed that of the most perfect vacuum obtainable on Earth. There is nothing to moderate the meteoric speed before it strikes the solid surface. Gravitation at the surface of the Moon is only one-sixth of that which we experience on Earth, and therefore the materials of the lunar crust are not likely to be as consolidated as terrestrial rocks. The meteorite may be expected to penetrate much farther than it could here with equal velocity. But the velocities are far from equal, as we have already seen. Now, a velocity of forty miles a second represents 1,600 times the energy of a velocity of one mile a second. If a velocity of forty miles a second is destroyed in one-tenth of a second, by a constant resistance, the meteorite will penetrate two miles into the resisting medium. In that brief interval whilst forcing its way into the Moon's crust its entire store of energy of

translational motion is transformed into molecular heat agitation. When this transformation is complete every gramme of the meteor's mass is endowed with 474,700 calories of heat energy. Whilst traversing outer space the meteoric mass of iron or stone probably had a temperature very close to absolute zero. Now, in a tenth of a second, it is changed into a gas ever so far above the critical temperature of its most refractory constituent, but confined temporarily in a severely limited space. The pressure is so intense, the expansion so rapid, that there is no time for the superimposed or surrounding material to be liquefied. It is instantaneously shattered and ejected by an explosion five hundred times as powerful, and much more rapid, than that which would result if a quantity of dynamite equal in mass to the meteorite were detonated in a cavity within the lunar crust. The explosion commences before the onward motion of meteorite is stopped, and so the initial cavity widens out as it deepens. The subjacent materials are forcibly compressed, whilst those above and around are shattered and pulverized and hurled aloft. In a few seconds a vast structure is fashioned which may preserve for untold geological ages a record of its birth.

The meteoric hypothesis has never yet received due consideration, because the explosive character of the missiles has not been recognized. Proctor, Gilbert, and See, as well as the opponents of the theory, have compared lunar forms with those that might be produced by impact. From this point of view the third objection is unanswerable. Gilbert's suggestion that the meteorites were originally satellites of the Earth, but, finding their way into the neutral region between Earth and Moon, dropped vertically on to the surface of the latter, is not at all convincing. Even if the blows were vertical they could hardly produce the characteristic features of the great ringed plains. Proctor, when making the original suggestion, recognized this difficulty. He says: "Now, so far as the smaller craters are concerned, there is nothing incredible in the supposition that they were due to meteoric rain falling when the Moon was in a plastic condition. . . . If one judged solely by appearances one would be disposed to adopt somewhat confidently the theory that the Moon had had her present surface contour chiefly formed by meteoric downfalls during the period of her existence when she was plastic to impressions from without. I am, however, sensible that the great craters under close telescopic scrutiny by no means correspond in appearance to what we should expect if they were formed by the downfall of great masses from without. The regular and, we may almost say, battlemented aspect of some of these craters, the level floor, and the central peaks so commonly recognized, seem altogether different from what we should expect if a great mass fell from outer space upon the Moon's surface."

But the form produced by an explosion is very different from that made by the fall of an inert mass. We must therefore consider what structure we should expect to find as the result of the explosion of a buried meteorite. The problem may be divided naturally into two parts: (i.) What is the form of the cavity left by the ejection of the material? (ii.) How is the matter distributed on its return? The former question is the more difficult to answer; the latter is more surprising in its result.

THE FORM OF THE CRATER.

The pressure produced by the exploding meteor when its onward motion is stopped by the resistance of the lunar crust is equal in all directions. The resistance varies greatly. The downward pressure results in a consider-

able compression of the imperfectly consolidated materials below. The lateral pressure produces both compression and ejection of matter. The upward pressure, assisted by the reflection of gas from the consolidated surface below, carries all before it, and the disintegrated material is scattered with some approximation towards equal distribution in all directions in the space above the surface. The reflected lateral pressure causes some excess of material to be sent in directions near the horizon. The resulting cavity appears to be essentially saucer-shaped, as shown in fig. 1.

But the ejected fragments, after pursuing approximately parabolic paths, return, and their distribution must now be considered. Let us take an ideal case. Suppose matter to be thrown from a point in a horizontal plane, all with the same velocity, and in all possible directions equally distributed in the space above the plane. Suppose all the material to rest exactly where it falls. The problem is to determine the distribution of density on the plane.

Let the initial velocity be u, the acceleration of gravity be g; then the range on the horizontal plane of a particle which starts at an angle of elevation θ is $\frac{u^2}{g} \sin 2\theta$.

All the material which is projected at angles of elevation lying between θ and $\theta + d\theta$ falls on a ring whose outer and inner radii are—

$$\frac{u^2}{g} \sin 2\,(\theta + d\theta) \quad \text{and} \quad \frac{u^2}{g} \sin 2\theta.$$

The area of this ring is

$$\pi \frac{u^4}{g^2} \left\{\sin^2 2\,(\theta + d\theta) - \sin^2 2\theta\right\}$$

$$= \pi \frac{u^4}{g^2} \cdot \sin\,(4\theta + 2d\theta) \sin 2\,d\theta$$

$$= \frac{2\,\pi\,u^4}{g^2} \sin 4\theta\,d\theta$$

when $d\theta$ is small enough.

To find the quantity which falls on this strip, describe a sphere of radius r round the point. The area of the hemisphere above the plane is $2\pi r^2$. The area of the zone between the elevations θ and $\theta + d\theta$ is $2\pi r \cos\theta \,.\, r\,d\theta$. The ratio of this area to that of the hemisphere is $\cos\theta \,.\, d\theta : 1$.

If M is the total mass, that which is ejected at elevations from θ to $\theta + d\theta$, and thus falls on the ring under consideration, is $\mathrm{M} \cos\theta \,.\, d\theta$.

But this is not the only matter that falls on this particular ring. All that starts at elevations ranging from $90° - \theta$ to $90° - (\theta + d\theta)$ falls on the same strip, and its quantity is $\mathrm{M} \cos\,(90° - \theta)\,d\theta$ or $\mathrm{M} \sin\theta \,.\, d\theta$. The total quantity which falls on the strip is therefore $\mathrm{M}\,(\sin\theta + \cos\theta)\,d\theta$.

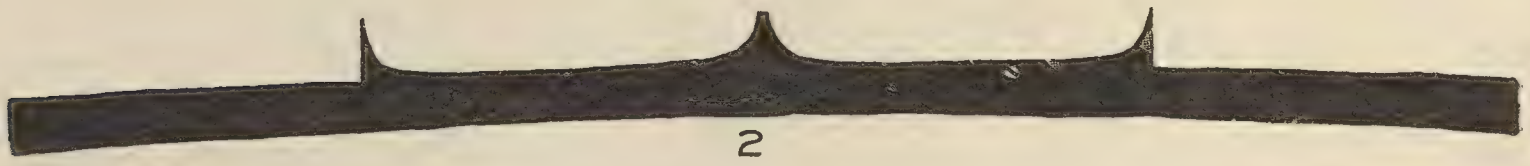
The density on this ring is

$$\frac{g^2\,\mathrm{M}}{2\,\pi u^4} \cdot \frac{\sin\theta + \cos\theta}{\sin 4\theta}$$

which reduces to

$$\frac{\sqrt{2}\,g^2\,\mathrm{M}}{2\pi\,u^4} \cdot \frac{\sin\,(45° + \theta)}{\sin 4\theta}$$

1



2

3

4

5

6

FIG. 1.—Crater formed by the ejection of material.

FIG. 2.—Graph showing theoretical density of material returned on to a plane surface.

FIG. 3.—The form as modified by material settling at the natural angle of slope.

FIG. 4.—No. 3 superimposed on No. 1 gives the theoretical form of a typical lunar crater.

FIG. 5.—A section of the crater Copernicus.

FIG. 6.—A section of the crater Theophilus.

This gives the form shown in fig. 2, which, however, could not actually be produced, for two reasons: the material, instead of forming vertical cliffs, would roll down and assume the natural maximum slope; and the material forming the extremity of the ring arrives in directions making an angle of 45° with the horizon, and cannot therefore build a steeper slope. The theoretical distribution of the returning matter is that shown in fig. 3. When this is superimposed on the crater (1) the result is shown in fig. 4. The resemblance to typical ringed plains on the Moon is very striking, as may be seen by comparing this figure with the sections of Copernicus and Theophilus shown in figs. 5 and 6.

The typical form of a lunar crater, then, agrees exactly with what might be expected as the result of explosion.

The next question is whether the available energy is sufficient to do the work. We must compare the energy of a meteorite with that of the best-known high explosives. The following table enables this comparison to be made as soon as the velocity of impact is known.

Energy in Calories per Gramme.

Tri-nitro-toluene (T.N.T.)	924
Tri-nitro-benzene	940
Tri-nitro-phenol (picric acid)	914
Tetryl	1,094
Nitroglycerine	1,478
Dynamite (about)	1,100

A meteorite moving with a velocity of—

1	mile per second	310	
2	miles per second	1,239	
3	,,	2,779	
4	,,	4,747	
5	,,	7,745	
6	,,	11,120	
7	,,	15,180	
8	,,	19,830	
9	,,	25,090	
10	,,	30,980	
15	,,	69,750	
20	miles per second	123,900	
25	,,	193,800	
30	,,	277,900	
35	,,	379,800	
40	,,	494,700	
50	,,	774,500	
100	,,	3,098,000	
200	,,	12,390,000	
300	,,	27,790,000	
400	,,	49,470,000	

This table shows that when a meteorite strikes a surface with a velocity of many miles per second it becomes an explosive compared with whose violence that of dynamite is insignificant. If the velocity is reduced to one or two miles a second it is rendered comparatively harmless. All the ordinary high explosives enjoy, however, one handicap that is of considerable importance when comparing their power with that of slowly moving meteorites, but which is quite negligible when we deal with masses moving with cosmic velocities. This handicap consists in their starting from the temperature of their surroundings, whilst meteorites in all probability are initially almost absolutely cold. The exact value of this handicap is not easily determined, but by considering what is known of specific and latent heats it seems probable that it does not exceed 1,000 calories per gramme. When dealing with millions, or even with hundreds of thousands of calories, this is of no importance. After the first thousand calories have been used in raising the temperature of the meteorite from absolute zero and

vaporizing it, the rest of its vast store of energy is available for pulverizing and scattering the materials into which it has penetrated so deeply. The mass of the ejected material may exceed that of the original meteor thousands of times.

The diameter of the crater produced by an explosion depends on the velocity of projection, and it is surprising how small are the velocities of the projected materials required to produce the craters of the Moon. A speed of one mile per second, owing to the small lunar gravitative power, would give a range of 985 miles, thus producing a ring 1,970 miles in diameter. Very few even of the vast lunar rings require a velocity of ejection of more than a quarter of a mile per second. Now, a velocity of forty miles a second implies energy 25,600 that due to a quarter of a mile per second. Thus a rapidly moving meteor may eject more than 25,000 times its own mass.

The following table gives the diameter of the craters produced by different velocities of ejection. Let V denote the velocity in miles per second with which material is ejected from a point on the surface of the Moon, and D the diameter in miles of the resultant crater.

V.	D.	V.	D.	V.	D.	V.	D.
·01	·197	·09	16·96	·17	56·93	·25	123
·02	·788	·10	19·70	·18	63·8	·26	133
·03	1·77	·11	23·84	·19	71·1	·27	144
·04	3·15	·12	28·37	·20	78·8	·28	154
05	4·92	·13	33·29	·21	86·9	·29	166
·06	7·09	·14	38·61	·22	95·3	·30	177
·07	9·65	·15	44·32	·23	104	·31	189
.08	12·61	·16	50·43	·24	113	·32	202

The following are the diameters of a few well-known lunar craters for comparison: Grimaldi, 147 miles; Clavius, 142; Ptolemaus, 115; Theophilus, 64; Plato, 60; Copernicus, 56; Tycho, 54; Archimedes, 50; Eratosthenes, 37; Autolycus, 23; Kepler, 22; Messier, 9; Linné, 5; Hyginus, 4.

We are now in a position to answer the three main objections to the meteoric hypothesis. Whilst the third one is undoubtedly valid when used against previous forms of the hypothesis, none hold against the explosive modification. Although it is certain that meteorites must strike the Moon obliquely, we need not expect to find any trace of the original scar. Whenever a meteorite penetrates into the crust the marks of the ingress are completely blown away by the resulting explosion. Whatever the angle at which the meteorite strikes the surface, the explosion acts radially outwards; and, as we have seen, the material is distributed so as to form a mountain-ring surrounding a saucer-shaped depression, in the centre of which there may be a central peak or group of mountains.

Our answer to the other two objections must depend largely on the view we take of the origin of the solar system. If we consider it to have originated in the whirling coalescence of two suns we shall have no difficulty in accounting for the abundance of meteoric matter throughout the whole region of the ecliptic plane. The outer tidal protuberances thrown from the suns provide not only the nuclei of the planets and their satellites, but the vast supply of meteoric material which has since been gathered in by them, and also the innumerable small masses that still circulate round

the Sun. There is thus no difficulty in agreeing that the meteorites which bombarded the Moon in the early days of its separate history must have been extremely numerous and many of them large. But when we realize how vastly the mass scattered may exceed that which explodes, we see that they need not have been nearly as massive as is usually supposed.

HISTORIC METEORITES.

The present abundance of meteoric matter in the solar system gives impressive evidence as to the conditions that must have prevailed in the distant past. It is estimated that twenty million visible meteors enter the Earth's atmosphere in twenty-four hours. The majority of these are very minute, but large ones are occasionally observed. The great collection in the South Kensington Museum contains meteorites ranging from tiny bodies up to masses weighing several hundredweight, representing nearly six hundred distinct falls, of which more than half were actually observed. Several have been seen to explode whilst still high in the air. One scattered fragments over an area seven miles by four in the United States. Nearly two hundred pieces, weighing altogether 800 lb., were picked up, the largest fragments being 74 lb. and 48 lb. respectively.

Again, in Ireland, in 1813, one fragment weighing 74 lb. and another 65 lb. fell three miles apart, with others scattered between.

On the 14th May, 1864, there burst over France a meteorite whose diameter is estimated to have been some hundreds of yards. Nearly a hundred fragments of it were found over a tract of country fifteen miles long. A mass of 260 lb. weight fell in Alsace in 1492, and penetrated to a depth of 5 ft. One which passed over England from Somersetshire to Cornwell on the 6th November, 1869, is estimated to have travelled 170 miles in five seconds.

At Knyahinya, Hungary, in 1866, a meteorite scattered fragments, more than a thousand of which were found. The main mass, 547 lb. in weight, made a hole in the ground 11 ft. deep. Two separate instances are on record in which the number of fragments scattered by a single fall reached a hundred thousand.

The velocity with which a meteorite strikes the Earth is astonishingly small. Some have been seen to rebound from ice 2 in. or 3 in. thick. Experiments by Professor A. S. Herschel show that the meteorite which fell at Middlesborough on the 4th March, 1881, struck the ground with a velocity of 412 ft. per second.

RECURRING METEORIC SHOWERS.

Further evidence is provided by recurring meteoric showers. The well-known November Meteors, in an immense swarm, traverse a vast orbit round the sun in thirty-three years. The stream is not less than 100,000 miles wide, and its length exceeds it width about sixteen thousand times. The Earth crosses the orbit of this swarm between the 13th and 16th November each year, and three times in a century finds the swarm passing. The meteors are flying at the rate of twenty-six miles a second, but it takes more than two years for the swarm to pass a point, so that displays may be seen in two successive years. The most magnificent on record was that of 1866. In view of the fact that the Sun, the Earth, and the Moon, all the planets and their satellites, have been perpetually gathering up meteorites ever since they acquired separate existence, the

great abundance shown by the present rate of gleaning gives some faint idea of the magnitude of the original harvest.

THE ONE REMAINING OBJECTION.

Only one objection now remains to be considered. Why does the Earth not show evidence of a similar bombardment to that suffered by the Moon? There are two good reasons, either of which by itself would afford sufficient explanation. One is that the Earth was probably liquid at the time when the lunar surface acquired its characteristic markings, and was therefore unable to retain any permanent impress of the blows showered upon it. The other is that then, as now, it was probably protected by its surrounding atmosphere.

Nearly all the meteorites that are encountered by the Earth or Moon are probably moving in long elliptic orbits round the Sun. Their velocity when crossing the Earth's orbit is about twenty-six miles per second, and that of the Earth is eighteen miles and a quarter per second. The resultant velocity of impact may therefore vary within wide limits. The gravitation of the Earth and the Moon will produce only a slight modification. In its passage through the atmosphere the velocity of a meteorite is reduced, as we have seen, from twenty or forty miles a second to a small fraction of one mile per second. On striking the Earth it has, perhaps, one two-thousandth part of the energy which it possessed before encountering resistance. A considerable fraction of this remaining stock of energy is required to raise the mass to incandescence. The rest is unlikely to be sufficient to cause any explosion. A meteorite which fell in Mexico in 1885 was seen within the hole that it made in the ground like a ball of fire. Next day it looked like an ordinary piece of iron. Most are only heated on the surface. A meteorite striking the Moon has a very different history. Encountering no atmospheric resistance, it strikes the surface with full cosmic velocity, penetrates deeply into the unconsolidated material, and explodes with a violence which it is easy to calculate but hard to conceive. No objections to the meteoric hypothesis, hitherto published, take into account the explosive character of a cosmic body arrested in its flight. It is desirable that the origin of all the lunar features should be studied from this point of view.

Space forbids the discussion here of other lunar forms, but it seems likely that this modification of the meteoric hypothesis will suggest explanations of their origin. For instance, a rill joining several craterlets recalls the splitting of rock by a line of wedges. The linear arrangement of the craterlets may be due to meteorites, spread along an orbit, meeting the moving Moon. It is generally suggested that the rays from Tycho may be cracks filled with light-coloured lava. What but the blow of a mighty meteorite is capable of shattering the lunar crust and producing the hydrostatic pressure to inject into the cracks the lava from below? The Maria are generally believed to have been deluged with very liquid lava, which obliterated most of the pre-existing craters, and, by consolidating the crust, caused a general lowering of level over a wide area. What more likely source is there for the heat which melted all this rock, or for the energy which broke the crust and flung the debris to such distances, than the impact of a massive meteoric swarm? The explosive character of arrested meteorites may provide a key to many of the mysteries connected with the history of the Moon.

PROGRESS IN RADIO-TELEPHONY.

By A. GIBBS, M.I.E.E.

THE use of radio-telephony, on small and medium powers, received great impetus during the war, and later developments of broadcasting have combined to hasten its development. For connecting isolated places where skilled telegraphists are not available, or are not warranted by the volume of traffic, it possesses unique features.

Its use as a means of communication for long-distance transmissions is not yet commercially developed. In this connection recent successful transatlantic tests are of great interest. These were conducted by the American Telephone and Telegraph Company in conjunction with the London branch of the Western Electric Company, the high-frequency power used being about 60 kw., supplied by a bank of valve oscillators each of 10 kw. capacity. The season of the year was favourable for radio transmission.

These tests amply demonstrated the theory that only a portion—known as a "side band"—of the modulated wave need be propagated through space. The system is called the "single-side-band carrier-eliminated method of transmission."

Under ordinary methods, when a high-frequency carrier is modulated in amplitude by speech frequencies, the power given out is not confined to the single frequency of the original carrier wave, but is spread out over a band of frequencies, so that the wave has somewhat the same characteristics as a spark transmission, and is said to be highly damped. This frequency range may conveniently be considered in three parts—(1) Energy at carrier frequency; (2) energy comprising a band of frequencies equal to the carrier frequency plus speech frequencies; (3) a band of similar width to (2), but extending downwards from carrier frequency.

The carrier-frequency energy is normally about two-thirds of the total even with the best modulation, and the carrier-frequency component does not contribute towards intelligible speech, which is the function of the high-frequency side bands extending over the complete range of the speech frequencies. As each of the side bands transmits power representing the complete message, one of them can safely be eliminated, and only one of these ranges of frequency transmitted. At the receiving end a locally generated carrier is supplied which remodulates, or beats with, the side-band frequencies. Thus, if the original carrier frequency was 55,500 cycles, this would be supplied locally, and a difference-frequency band of, say, 3,000 cycles—the voice-frequency band—would result from modulation with the locally generated frequency.

This method of transmission is somewhat complex, for the transmitted side band is first developed by modulation and filtration at low power, and then its power is built up to a large value in a succession of powerful amplifiers. The development is of great importance, and has realized desirable economies in power and in restricting the transmitted wave-length band.

The conservation of wave-frequency bands is of paramount importance, owing to the rapid increase of long-distance stations and the consequent demand for elbow-room in the direction of wave-length channels. Further,

ten telegraph-radio channels can be worked in the frequency band required by one ordinary radiophone channel.

Incidentally it may be remarked that unless methods improve there appears to be some danger that the available frequencies for long-distance work may shortly be exhausted, and that countries that delay their long-distance radio plans too long may find themselves in an unfavourable position with regard to wave-length allocations.

SHIP AND SHORE RADIO-TELEPHONY.

This subject is becoming one of general interest and inquiry. One of the problems that is now coming into prominence is the provision of telephone communication between telephone-exchange subscribers in any area and ships at sea. In this demand radio-telephony is only following on the lines of wire-telephony, which has to a great extent supplanted wire-telegraphy in popular favour. The spoken word between correspondents, with its immediate response, and its opportunities for discussion, is vastly more satisfactory and conclusive than the exchange of telegrams. It may therefore be expected that the demand for telephone connection with points outside the scope of the land-line network and the telephone limitations of the submarine cable will be an increasing one. Can it be met? And what are its special problems?

It will be well to recall at this point just what it is that makes possible automatic repetition or through transmission between the wire and radio channels. The automatic repetition from the wire to the outgoing radio-channel is made possible through ability to control the transmitted wave-power by the voice-currents set up at the distant end of the telephone-line. In the early radio-telephone art, before the vacuum-tube, modulation was effected by a microphone transmitter inserted in the antenna, which required that the speaker be present at the radio-station. It is therefore the electric control type of modulator, such as the vacuum-tube, as distinguished from the air-wave-control modulator, which permits of the talker being at the far end of a wire circuit. Conversely, in the receiving-channel, it is the fact that the detecting action at the land radio-station yields electric currents directly, ready for propagation over a wire circuit, that enables the radio-channel to be extended to a distant listener.

Thus it is the thermionic-tube modulator and detector which have made possible the radio-wire transfer. It is the thermionic tube as a reliable high-quality amplifier, however, that makes the transfer practical; for it is the amplifier which enables the weak voice-currents received at the radio-station from a land-line subscriber to be boosted to power proportions, and thus control the considerable radio-frequency power required for transmission; and, again, it is the amplifier which enables the extremely weak currents received from the radio-link to be so augmented that upon being placed upon a wire circuit, and perhaps being further amplified *en route*, they may be heard in the regular telephone at the other end.

A brief reference to the operation of wire-to-wire toll-circuit service will serve to elucidate the problem.

In general it may be said that land-line toll conversations may radiate in all directions. When required, the number of circuits can readily be increased; the wires may be so disposed as to make extraneous interference or induction negligible; once established, the volume of the speech is maintained within narrow limits, and the number of simultaneous conversations is limited only by the number of circuits provided.

Let us now compare these conditions with those of the radio-wire circuits handling, say, three simultaneous conversations. In a land-wire toll conversation the subscriber has been educated to cut in on the conversation at any stage. This is possible because the transmitter and receiver at both ends are permanently connected to the line. In ordinary radio-telephone practice the line—*i.e.*, the antenna—is not so connected, but by means of a switch it is alternately connected to the transmitter and receiver. This is sometimes called "non-duplex" or "push-button" radio-telephony, and resembles the earliest telephone practice, where one spoke and then switched over to the receiver to listen.

There are two principal methods of avoiding this switching and leaving the antenna connected to both transmitter and receiver: (1) The receiving-apparatus may be electrically and magnetically balanced so that it is not affected by the outgoing power; (2) different frequencies may be selected for transmission and reception, and reliance placed upon balancing and upon sharply tuned frequency-selecting circuits for non-interference. The land station, having more scope, may in addition have his receiving-station some distance from his sending-station. A junction station will then be required to connect the wire-line to its two radio-channels. The latter or two-frequency method is simpler, but in any case the ship-station plant has become more complicated than that required for a wireless-telegraph station or a simple non-duplex radio-telephone station, and greater demands have been made upon the available wave-length bands.

To connect the radio-channel with the wire-channel, and to permit of both-ways speech without mutual interference, involves, in addition to the radio requirements, the application of the highest developments of wire-telephone repeating practice. At the junction-point between the land-wire circuits and the radio-channels very careful arrangements must be made to maintain the electrical separation of the frequencies used respectively for speech to and from the ship, and for connecting the land wire to the sending radio-channel on the one hand and the receiving radio-channel on the other. A balancing network and a special repeating-coil which is a development of the telephone repeater and the carrier current art are employed at this junction-point. The arrangement resembles a Wheatstone bridge—the radio transmitter and receiver being in the detector and generator branches respectively, and therefore mutually non-interfering, while the two-wire land line corresponds to the X arm, and the balancing network to the artificial arm of the bridge.

At the shore radio-station there is now the problem of handling simultaneously three two-way conversations originating at different points and intended for different ships. There are several more or less practicable ways of doing this. Broadly, one antenna may be used for all three transmissions, and one or three independent radio-transmitters may supply it with the three-voice modulated carrier waves, or even with one carrier wave triply modulated. Such refinements are somewhat critical in adjustment, involve power-losses, possible overloads, and cross-talk, and impose undue complexity upon the ship equipment. The simplest method would therefore be to erect at the radio-station three separate but closely adjacent antennas and three separate valve transmitting-sets, each sending out its own particular frequency, modulated by its own speech-currents, which have been received over the land lines through the repeating network at the junction-centre. This provides three transmitting-stations in one building.

At the receiving-station there must now be three receiving aerials and equipments. Loop reception would be employed, and full advantage taken of the directive and selective properties of such antennas.

FLUCTUATIONS OF SPEECH INTENSITY.

The maintenance of a standard intensity of speech (or transmission value) presents another problem. Once a wire-to-wire toll communication is established no great difficulty is experienced in maintaining it, even if the toll circuit includes repeaters, because the wire conditions are practically constant.

But in the case of a ship the transmission value of the radio-link fluctuates within wide margins, for the following reasons :—

(1.) The ship's position and its distance from the coast station are variable quantities. Adjustments in the amplification must therefore be made at the coast station and at the ship station, if a predetermined standard of speech is to be maintained both ways. This involves skilled attention at frequent intervals, both on account of the movements of any particular ship and of the wide separation and different signal-strengths of ship stations generally. Quite recently elaborate tests were taken between special experimental stations by the American Telephone and Telegraph Company, U.S.A. It was found that with a vessel travelling at ten miles an hour the changes in intensity of the received signals were such as to require readjustment of the amplification every half-hour to keep the transmission-value as constant as is done in wire-to-wire practice.

(2.) The radio medium itself undergoes great fluctuations. During the day considerable atmospheric absorption takes place (although the conditions are more constant than at night), and during the dark hours, although greater distance can be achieved, great fluctuations take place even during a short period of time. This also implies a considerable amount of care and attention by the toll staff in order to compensate for these changes and maintain fairly constant and satisfactory conditions. In the experimental tests just referred to it was found that an enormous difference existed between day and night signals. At distances of 1,000 miles, using a 400-metre wave, night to day signal ratios were at times of the order of 100 to 1, or a power ratio of $(100)^2$ to 1. These day to night differences in signal-strength are familiar to listeners-in to distant radio-signals. To overcome such differences longer waves and greater power will apparently be necessary, particularly during the day.

The fluctuations occurring during the night period, although smaller than the day-to-night fluctuations, have a marked effect upon transmission. They may easily be 10 to 1 in field strength, equivalent to 100 to 1 in power. These fluctuations occur with great rapidity, rendering it a difficult matter to maintain the circuit satisfactory for regular and uniform telephone service. The cause of these rapid fluctuations has been elsewhere referred to, and may be attributable either to irregular reflections and refractions at the Heaviside layer or to variations in atmospheric absorption. The radio-listener to long-distance short-wave stations is again familiar with this problem.

INTERFERENCE.

In addition to these fluctuations, due to variations in what might be called the propagating co-efficient of the medium, there arises another difficulty, due to interference from other stations operating in the same medium, particularly spark stations, whose transmissions can be felt over a considerable band of wave-lengths. Near-by transmissions of this kind

can force their way into the most selectively tuned circuits and add their quota to the troubles of the telephone engineer (not to mention the long-suffering amateur). Then there is the interference due to static or atmospheric electrical disturbances. It will be seen that the radio channel or medium is much more liable to fluctuation and interference than the wire-toll line.

For these reasons, and in view of the greater complexity of a multi-channel ship-to-shore radio-telephone service, it will readily be understood why greater progress has not been made in the practical realization of this problem.

In connection with the experiments referred to, and in illustration of what is possible in spite of these difficulties, it may be mentioned that a ship in the Atlantic was put into speaking communication with Catalina Island radio-telephone station in the Pacific, right across the Continent of North America. The conversation was relayed by a radio-telephone coast station near New York to the cross-continental toll-line system of the American Telephone and Telegraph Company, then transferred by a Pacific coast radio-station into the radio-channel to Catalina Island. The cross-continental toll system has a number of repeating-stations which make good the losses of the various stages of land line. The achievement was an experimental one, and not up to commercial requirements, but none the less remarkable. It shows the possibilities of radio-wire channels.

It is not too much to predict that the connection of the land-line telephone-system will in due course be extended to ships at sea. The subject is to a considerable extent an economic one, but its absolute success depends in a large measure on a better understanding of the radio medium —the ether—and a greater skill than at present exists in compensating for its vagaries, and the interfering properties of its multitudinous wave-systems.

PETROLEUM: ITS HISTORY, GENESIS, AND GEOLOGY.

By Professor JAMES PARK, F.G.S., F.N.Z.Inst.

HISTORICAL.

THE rise of the petroleum industry is one of the romances of the present day; and this is all the more surprising when we remember that petroleum and its products were known and used scores of centuries before the Christian era. Antiquarian research has shown that asphalt was employed as a mortar in the construction of buildings over four thousand years ago. The Old Testament tells us that asphalt was used in the walls of the Tower of Babel; and Herodotus, a celebrated Greek historian who lived in the years 490–520 B.C., mentions that the stones in the walls of Babylon and Ninevah were cemented with asphalt. In America, the ancient Aztecs of Mexico and Incas of Peru, who had already reached a high stage of civilization and culture when Rome was young, used much asphalt in the construction of their temples and dwellings.

The Ark of Noah, and the bulrush basket that carried Moses the to care of Pharoah's daughter, were made waterproof by the application of pitch. Among the Egyptians petroleum was used in the art of embalming

the dead; and the word "mummy" is believed to be derived from *mumiya*, the Persian for asphalt. From time immemorial petroleum has been used for lighting the cities of the Red Sea. Marco Polo, the Venetian traveller of the thirteenth century, relates that the Russians of the Baku region drank petroleum as a cordial and as a medicine; but recent research has shown that the Persians sought the oils of Baku many centuries before the Russian occupation of the Caucasus.

In consequence of its many uses and weird properties, natural oil and its derivatives became objects of adoration and worship among the ancient inhabitants of western and central Asia. Most famous were the "eternal fires of Surakham," on the shore of the Caspian Sea, where the Parsees erected shrines and temples, to which they made pilgrimages, as far back as 600 B.C. A modern Hindu temple, about two hundred years old, now marks the site of the ancient Caspian shrines. The "eternal fires" were merely seepages of the combustible gas methane, common in all oilfields, and which, when once ignited, continue to burn.

The first attempt to produce petroleum on a large scale was made in Russia. In 1723 Peter the Great granted a monopoly of the Baku oilfields to a private company. This concession remained in force till 1872. But it was in the United States that the production of oil first grew into an industry of economic importance. The first American oil company was incorporated in Pennsylvania in 1854. Like many other pioneer ventures, it failed to achieve success, and was reorganized in 1858. The new company began operations by drilling the first well put down in the American Continent for the production of oil. Oil was struck at a depth of about 60 ft., and thereafter the development of the petroleum industry was rapid. Scores of wells were drilled along the course of the Allegheny River, eventually resulting in the discovery of the Appalachian oilfields, for many years the leading producer in America.

Up till 1860 the production of mineral oil from carbonaceous shale, by a process of destructive distillation, was a flourishing industry in the Lothians of Scotland; but from that year onwards up till 1880 the shale-oil industry was completely paralysed by the large output of natural oil in America. In the early "eighties" the discovery of a cheap process of saving ammonium sulphate and other valuable by-products contained in the shales rejuvenated the Scottish oil industry.

The success achieved by drilling in America once more directed public attention to the Russian oilfields. Drilling in the Baku region by a private company was attended with extraordinary success; but, notwithstanding the large number of flowing wells, progress was everywhere hampered by the lack of transport facilities. In America the transport difficulty was in part overcome by the construction of pipe-lines for the conveyance of the oil to distributing-stations, where it was filled into wooden barrels; but it was soon discovered that the cost of the barrels exceeded the value of the oil.

The problem of the economical transport of the oil remained unsolved till 1879. In that year a Russian firm constructed a tank-steamer, specially designed for the carrying of oil in bulk. A combination of the American pipe-line and the Russian tank-steamer triumphantly solved the problems of land and oversea transport, and since 1880 the development of the petroleum industry has been phenomenal.

The ease with which large quantities of oil can be carried and stored has led in recent years to the adoption of oil fuel for the warships of Great Britain and the United States; and at the present time many ocean-going merchantmen are being converted to oil-burners. The invention of the

internal-combustion engine has given a tremendous impetus to road transport. It made possible the flight of machines heavier than air, thus realizing the dream of inventors throughout the past centuries. What effect this may have on the destiny of mankind the future alone can disclose.

Up till 1902 the American and Russian output ran "neck and neck," but the discovery of prolific oilfields in California and Texas gave America a commanding lead in 1903. Since then the tremendous production of the State of Oklahoma and the increased output of California have enabled the United States to leave Russia and all other competitors far behind. At the present day about two-thirds of the world's output of petroleum comes from the United States. After Russia comes Mexico; and the remaining oil-producers, arranged according to their output, are Rumania, Dutch East Indies, Galicia, Japan, and Peru. In recent years valuable oilfields have been discovered in Mesopotamia, which is at present occupied by Great Britain under a mandate granted by the League of Nations.

The increasing use of petrol for the driving of motor-cars, motor-wagons, and tractors, of barges and oil-launches, of submarines and aeroplanes, makes the possession of oilfields a matter of supreme importance. When the oilfields become exhausted, as they surely will in a few decades, increasing attention will be directed towards the production of combustible distillates from wood, oil-shale, and lignitic coals, of which the world possesses a vast undeveloped store.

CHEMISTRY OF PETROLEUM.

Petroleum is a mixture of carbon and hydrogen compounds, of which there are many possible combinations. Altogether eighteen have been identified, and are called the "hydrocarbon series."

One of the most important carries C and H in the ratio of twice as many plus two H atoms as C atoms, which may be expressed by the formula C_nH_{2n+2}. This represents the methane or paraffin series.

The molecules may carry a few or many atoms. The fewer the atoms in the molecule the more volatile is the substance. Thus CH_4 is a gas (= methane), while $C_{20}H_{42}$ is a solid (= paraffin).

Another series carries carbon and hydrogen in the ratio of two H to one C, and the number of atoms may range from C_2H_4 to $C_{30}H_{60}$. Two series have this composition—one the olefine series, which is unstable; the other the naphthene series. The paraffin and naphthene series are by far the most important constituents of natural oil and gas.

Natural Gas.—This consists dominantly of CH_4 with, as a rule, a small amount of N, and traces of CO_2, CO, O, helium, and H_2S. The composition ranges from—$CH_4 = 64$ per cent. to 98·9 per cent.; $N = 0{\cdot}75$ per cent. to 6·3 per cent.

Petroleum.—All natural oils are called petroleum. They are a mixture of the hydrocarbons of the paraffin series and of the olefine and naphthene series.

Oils in which the first predominates are called paraffin-base oils, while those carrying the second in greatest amount are called asphalt-base oils. It should, however, be noted that there is no sharp line dividing asphaltic and paraffin oils. Many asphaltic oils contain solid paraffin, and some so-called paraffin oils yield an asphalt residue.

The composition of natural oils shows a great range, as—Carbon, 79 to 88 per cent.; hydrogen, 9·6 to 14·8 per cent.; nitrogen, 0·02 to 1·1 per cent.; sulphur, trace to 4 per cent. The sulphur may be free or occur as H_2S.

The specific gravity of oils ranges from 0·73 to unity. It is usually expressed in terms of degrees of the Beaume scale.

ORIGIN OF PETROLEUM.

Natural oil is generally believed to have originated from the destructive low-temperature distillation of organic matter buried in aqueous rocks. In other words, it is the result of low-temperature distillation at high pressure by natural processes that are not difficult to imitate successfully in the laboratory. Molluscs and other marine organisms, peat, shale, and coal are all probable sources of oil.

There is also the inorganic hypothesis, which describes the genesis of petroleum to the action of metallic carbides in the interior of the earth. This view has not much support.

As we have already seen, oils differ widely in composition, and this may have arisen in part from differences in the character of the organic matter that furnished the hydrocarbons.

GEOLOGY OF PETROLEUM.

Oils are rarely found in the place where they were originally formed; and when I say "formed" I mean liberated as a chemical distillate from the parent organic matter. As a rule they migrated along the line of least resistance till they met a porous stratum, which, becoming saturated with oil, acted as an underground storage reservoir.

Profitable oil-pools occur in Palaeozoic and Mesozoic rocks, but most of the world's great oilfields are in Tertiary formations.

Clays possess the property of fractionizing oil into two fractions—namely, a light oil which separates from the clay, and a heavy oil which is retained. This property of clay may, I think, account for some of the differences of composition of natural oils.

Reservoirs of Oil and Gas.—Sandstones and sands are the common types of reservoir rocks. The amount of oil a sandstone may carry is determined by the number and size of the openings it contains. The greater the porosity the larger will be the amount of stored oil. The greatest amount of pore-space is possessed by rocks composed of round grains of uniform size; the least by sandstones composed of angular grains of various sizes.

Hard, well-cemented sandstones constitute the storage rocks in the Appalachian oilfields, in Illinois, Kansas, and Oklahoma; and soft, friable sandstones the reservoirs in Wyoming, Colorado, Northern Texas, and Louisiana. The oils of California, Russia, Galicia, Rumania, and Peru come from unconsolidated beds of sand.

According to the amount of pore-space, sands are called "close" or "tight" when they possess a low degree of porosity, or "open" when they possess high porosity. A porosity of 10 per cent. is equal to 750 barrels of oil per acre-foot. The recoverable oil ranges from 50 to 75 per cent. of the oil in the sands.

Testing for Oil in Sand.—Take a sample of the outcrop rock, and treat a few ounces of the fragments with ether for half an hour in a well-stoppered bottle. The ether will dissolve any hydrocarbons that may be present. Then pour the liquid into a white porcelain dish. The ether will rapidly evaporate and leave a ring of oil, which will be greenish-amber or pale brown in the case of high-grade paraffin-base oils, and range from dark brown to black in the case of asphalt-base oils.

Shape of Oil-reservoirs.—Some sandstones occur in well-defined beds of more or less constant thickness, and extend over large areas. But as

a rule sandstone beds are lenticular, thinning out in all directions. Oil will be found only in the porous part of the rock.

Shelly and coralline limestones often yield oil, especially the dolomitic kinds. Dolomitic limestones are the reservoir rocks in some parts of Ohio, Texas, and Persia. Oils derived from limestones usually belong to the asphalt-base series.

A porous stratum of sandstone or bed of sand can only form an effective reservoir when it is contained between impervious beds, of which the commonest kinds are clays, shales, and other fine-grained aqueous rocks. Occasionally the enclosing rocks are similar to the reservoir rocks, but so tightly compacted or so fine-grained as to prevent the migration of the oil. In the absence of a covering impervious stratum the oil may become dissipated throughout a great thickness of rocks which, as a consequence of their character, may be incapable of storing the oil in pools of a profitable size. It is as a consequence of such conditions that alluring surface seepages of oil and gas seldom develop into flowing wells. Mere seepage wells are never profitable.

The Migration and Accumulation of Oil and Gas.

Of all sediments, marine muds contain the greatest amount of organic remains. But oil and gas are not common in marine clays, shales, or even limestones, hence we conclude that they have migrated from the parent source and become concentrated in rocks more suitable as reservoirs. Prominent among the causes that may have led to oil-migration are gas-pressure; differences in specific gravity of gas, oil, and water; pressure of underground water; rock-temperature; capillary attraction; and rock-movements.

Gas-pressure.—Gas-pressures up to half a ton per square inch are met with at oil and gas wells. This pressure, being exerted in all directions, is capable of forcing oil through a great thickness of rocks. Gas-pressure plays a useful role, as it forces the oil to the surface, and is the chief factor in producing flowing wells. Its efficiency as an agent of migration is unknown, but it is generally believed to be important.

Gasfields are of larger extent than oilfields, and may be quite distinct from them. At the same time, gas is common on most productive oilfields.

Differences in Specific Gravity.—Gas is lighter than oil, and oil than water. Oil and water are immiscible, therefore oil floats on water. And wherever oil and water are mixed in rocks the oil will rise above the water. Moreover, when water invades strata containing oil, the oil will be driven out by the water. Ground-water is never stagnant, but, on the contrary, is slowly circulating. Hence in the differences of the specific gravities of oil and water is recognized the most powerful cause of oil-migration.

Pressure of Ground-water.—The pressure of underground water is proportional to the depth or "head." It is the pressure arising from the head that enables water to drive oil and gas before it.

Rock-temperature.—The temperature of the crust increases at the rate of 1° F. for every 60 ft. to 200 ft. in depth, the increment varying in different places. Perhaps 1° F. for every 100 ft. is about the average temperature gradient. The tendency of this increasing rock-temperature will be to stimulate the circulation of water, oil, and gas; but this effect cannot be important except at depths exceeding 5,000 ft.

Capillary Attraction.—Liquids ascend through small openings and pores such as those in a sponge. An opening less than $\frac{1}{50}$ in. in diameter is called a "capillary opening." Liquids will rise in such openings against

the attraction of gravity, and the height to which the liquid will rise will depend on the nature of the liquid, size of the tube, and the material of the tube.

The effective pressure that forces liquids to ascend such tubes or openings is capillary pressure, which is a function of the surface tension of the liquid and the attraction between the liquid and the walls of the tube. The greater the surface tension the greater the capillary pressure, and consequently the greater the tendency to enter microscopic pores.

Water has a surface tension three times that of crude oil, and therefore exerts a capillary pressure three times as great as that of crude oil.

Since oil and water are disseminated throughout certain stratified rocks, it is evident that the difference in surface tension will cause a selective segregation of the oil and water in different zones and layers. The water, on account of its superior surface tension, will occupy the pores of smaller diameter, while the oil will be driven into those of larger size.

Capillary pressure decreases with rise of temperature; therefore, as a consequence of the increase of temperature arising from crustal heat, it is probably negligible at a great depth, though it must be an important factor in oil-migration at depths less than 5,000 ft.

Crustal Movement.—Rock folding and faulting set up crustal stresses that may tend to stimulate oil-migration, partly by mechanical stress, and partly by the increase of temperature arising from rock-pressure. In many places oil travels to the surface along fault-planes, such planes being often zones along which the wall rocks are crushed and shattered, thereby forming channels of low frictional resistance.

PRINCIPLES OF OIL-ACCUMULATION.

The laws governing the accumulation of oil were not clearly understood till 1885. In that year I. C. White, an American geologist, formulated the anticlinal theory of oil-occurrence, a conception which at once placed the study of oil geology on a scientific basis.

The sandstones and limestones in which pools of oil occur are in almost all cases folded into anticlines and synclines. Experience has shown that the anticlines are likely to carry oil.

Sandstones and limestones are in most cases underlain and overlain by shale, clay, or other impervious rock. If oil is introduced into a porous sandstone it will rise to the highest part of the anticline, forming a reservoir along the crest of the fold. If the sandstone is only partly saturated the oil will accumulate on top of the water along the limbs of the folds; if the sands are dry the oil will gather in the bottom of the synclines. But in the majority of cases oil-sands are completely saturated, and therefore the oil accumulates along the crests of the anticlines.

If gas is present in an oilfield, being the lightest constituent, it accumulates above the oil, as the oil does above the water. So that in the same anticlinal fold there may be gas, oil, and water at different horizontal zones, arising from their gravitational separation.

Summarizing the above reflections, we find that the essential conditions of oil-occurrence are—

(1.) Stratified marine rocks enclosing an abundance of organic remains.
(2.) A porous sandstone or sand-bed for oil-storage.
(3.) The presence of impervious beds below and above the storage sandstone.
(4.) A folded structure to permit the gravitational separation of the gas, oil, and water.

A favourable geological structure is a requisite condition of oil-accumulation in commercial quantity; but a perfect geological structure does not warrant the prediction of producing-wells. Only actual boring can determine the presence or absence of an oil-pool, and an accurate geological survey will always minimize the risk of failure. To disregard geological structure is to invite almost certain failure.

Favourable Rock-structures.

Any arrangement of the strata that will form a suitable trap for the accumulation of oil in commercial quantity is called a "structure." Structures occur in many forms, and some involve a complex arrangement of the beds.

The structures generally recognized are—

(1.) Folded structure, as in Appalachian and Californian oilfields.
(2.) Monoclinal or homoclinal structure, as in Ohio-Indiana areas.
(3.) Dome structure, as in Wyoming, Ohio, and Mexico.
(4.) Oilfields along fault-planes, as minor fields of California and Wyoming.
(5.) Oilfields along unconformities, as in Ontario and elsewhere.

Folded Oilfields.—All the important oilfields occur in folded rocks, and, besides the American fields mentioned above, include those of Russia, Galicia, Rumania, India, Persia, Dutch East Indies, and Peru.

The folds may consist of large isolated anticlines or of closely crowded anticlines and synclines.

The angle of dip of the limbs of the anticlines may be gentle, amounting only to a few degrees, or they may be steep, as in Wyoming, where dips of 45° are common. In California vertical and even overturned folds occur. The position of the oil-pools is to a large extent determined by the amount of water present in the storage rocks. In most cases these are completely saturated, hence the oil and gas occupy the crests of the anticlines.

Partial saturation means the occurrence of the pools on the limbs of the folds just above the ground-water level.

Long anticlinals are not always simple folds. There may be minor corrugations along the crest or axis of the main anticlinal. And here it may not be out of place to say that oil is seldom or never found in contorted or much-faulted Palaeozoic strata.

Fields with Monoclinal Dip.—In these the strata show a general dip in one direction only. Such a structure does not favour oil-accumulation and the formation of oil-pools. The rare exceptions that occur are due to change of angle of dip, or to change of direction of dip. A change of dip sufficient to cause a sensible flattening of the beds produces what is called an "arrested anticline." The dome or bulge arising from the change of dip may be of sufficient magnitude to permit an oil-pool of commercial value to form. A change in the direction of dip may cause the formation of a pucker in the rocks that may entrap oil, or retard its flow so as to allow oil to accumulate in small pools.

The Dome Structure.—Some of the world's most productive oilfields are situated on dome structures, as those of the Gulf Coast fields of Texas, Louisiana, and Mexico.

Volcanic Domes.—The most productive wells in Mexico occur in fields penetrated by igneous rocks as necks or plugs. The intrusion of the igneous rock has arched the sedimentary oil-bearing strata, and also fissured and shattered them.

Fields on Fault-planes.—A fault-plane containing an impervious layer of clay may seal an oil-bearing stratum. Only one side of the faulted strata

will afford the conditions for oil-accumulation. An igneous dyke may also act as an effective trap for oil.

FAVOURABLE OIL-INDICATIONS.

These include (1) seepages of oil and gas, (2) presence of salt water, (3) presence of oil residues at rock outcrops.

Seepages.—The quantity of oil and gas escaping at a seepage may be small or great. The presence of such a seepage is an evidence that the formation contains oil, but not necessarily in profitable amount. If a suitable rock structure exists there is sufficient warrant to undertake the search for oil by drilling.

Seepages are common along the outcrop of storage rocks. At such points the rock is unlikely to be a producer of oil, as the oil has not been accumulating but escaping at the surface. At some distance from the outcrop there may be an anticline or dome containing profitable oil. A seepage occurring at a distance from the outcrop is an encouraging feature. Seepages are only of value as showing that the formation is oil-bearing.

Salt Water.—Salt water is commonly met with in oil-wells. It is the sea-water contained in or entangled in the sediments when laid down on the floor of the sea. Salt water may or may not accompany oil, and its presence is no certain indication of oil below.

Residual Deposits. — Solid residuals, as asphalt, ozokerite, and solid paraffin, at the outcrop have the same meaning as seepages of oil and gas. They prove that the formation is oil-bearing, but afford no proof that oil exists in profitable amount. If met with in a well they are an unfavourable indication, as proving that the lighter hydrocarbons have evaporated, leaving only the heavy base in the rocks. Drilling down the dip side is not likely to meet success in the case of light oils.

Oil and Gas Traces in Wells.—Small quantities of gas and often some oil exist in all shales and marine clays. Small traces of oil and gas in a well are not a proof of the existence of oil or gas in commercial quantity.

It is well to bear in mind that the occurrence of oil-bearing shale is not an indication of the existence of underground reservoirs of oil, as erroneously supposed by many prospectors. Oil-shale is an intimate combination of clay and hydrocarbon compounds, and is incapable of yielding oil except by some process of destructive distillation, either natural or artificial.

Careful mapping of the Tertiary oilfields of Upper Burma has proved that an horizon that is carbonaceous in one locality may be oil-bearing in another, often within a distance of 400 yards; but that where the horizon is oil-bearing thick beds of impervious marl or clay are found to occur. Lignitic beds have been traced into oil-bearing strata containing no trace of vegetable-remains.

The seepages of oil found at Taranaki, and at Waiotapu in the King-country, New Zealand, occur in Tertiary rocks; and there is good reason for the belief that the oil has originated from the destructive distillation of the underlying seams of lignitic coal.

SELECTING SITE OF OIL-WELL.

In all cases the site of the well should be selected near the highest point of the anticline or structure. If a well thus situated strikes water the structure is probably unproductive. Should the well strike gas, a second well should be selected on the flank of the fold or dome, so as to reach the oil lying below the gas zone.

SOME REMARKS UPON COALS AND THEIR CLASSIFICATION.

WITH SPECIAL REFERENCE TO THE LIGNITES OF THE SOUTH ISLAND OF NEW ZEALAND.

By Professor W. P. EVANS, M.A., Ph.D.

(Continued from page 90.)

III. *Classification according to Chemical Composition.*

ALTHOUGH the methods of classification considered in this section are spoken of as based upon chemical composition, yet in many instances other characteristics of the coals are also made use of in deciding their final positions. Thus in one case it may be the character of the flame produced while burning; in another, the nature of the coke yielded by the coals. Still, all through the schemes great stress is laid upon the results of chemical analysis, thus justifying the general heading.

From what has been said with reference to the supposed origin of coals it may be anticipated that all, whatever be their actual age, will contain (1) a preponderating organic part, and (2) a varying—though generally small—amount of mineral matter derived partly from the original vegetable debris, partly from silts deposited at the same time as the debris, and partly from infiltrations or igneous intrusions.

The mineral matter of the coals, though in itself affording a study of great interest scientifically, and of some importance technically, need not be further considered here, since its effect as a whole becomes evident when the results of analysis are calculated on an ash-free basis.

The organic part consists chiefly of carbon, and hence the percentage of this element is usually looked upon as the most important of the factors determined by ultimate analysis. Next in importance comes hydrogen; and, fortunately, these two elements are directly determinable by any ordinary process of combustion analysis. Then come oxygen, an element which is sometimes, though it would seem unjustifiably, considered to be merely an impurity; nitrogen, another essential constituent of the vegetable debris; and sulphur, which, in part, must be looked upon as belonging to the true coal substance, at least in the lower-grade coals. The presence of these elements in the coal is easily shown, and the ordinary processes of chemical analysis are sufficient to determine with accuracy their relative proportions in the coal.

THE METHODS OF ANALYSIS AND THEIR LIMITATIONS.

The analysis upon which the classification is based may be either "proximate" or "ultimate." The former method has the advantage of simplicity, and may in some cases give a better picture of the constitution of the coal than the more difficult method which, as is implied by the term "ultimate," actually determines the proportions in which the elements composing the coal are present. This advantage of the simpler method is apt to be overlooked. To counterbalance this advantage, however, there is the disadvantage that the proximate analysis is made by proximate methods,

while the ultimate analysis is, or should be, made by the most refined methods available for such work. The former class of analysis therefore depends to a greater extent than the latter upon the consistent nature of the analyst's work, and never yields exact results. The work of one man is never, in this class of analysis, strictly comparable with the work of another man; but in ultimate analysis the results obtained by different workers at different times should be strictly comparable—they should not vary by as much as $\frac{1}{3}$ per cent.

It is certainly true that the methods of proximate analysis introduced—or, rather, reintroduced—during the last few years make it considerably more definite, and therefore more useful for classification purposes; but comparison between the results obtained by the older (crucible) methods and those by the more recent (retort) methods is not advisable. Many of the glaring inconsistencies to be found in partial classifications based upon the results of proximate analysis must no doubt be ascribed to the inherent defects of the older methods, but some appear to be due to carelessness in the use of those methods.

The essential factors determined by analysis are—

(*a.*) Proximate analysis—Water; volatile matter; fixed carbon; ash.

(*b.*) Ultimate analysis — Water; carbon; hydrogen; nitrogen; oxygen (by *difference only*); ash.

In each case a determination of organic sulphur is desirable—for some purposes, indeed, essential. Total sulphur is determined as a matter of course.

Both systems suffer from the fact that we have little or no real knowledge of the constitution of the coals analysed.

In a proximate analysis the whole yield of volatiles (water, of course, excluded) is taken together. These volatile compounds may have existed as such in the coal prior to, or have been formed during, that destructive distillation which is a necessary part of the analytical process. Certainly they include many different types of compounds, and hence the calorific value of 40 per cent. of volatiles from one coal is usually not the same as that of 40 per cent. from another coal. Yet the method makes them of the same value always. Similarly, the ultimate analysis treats 80 per cent. of carbon and 5 per cent. of hydrogen merely as so-much carbon and so-much hydrogen. They are taken simply as elementary constituents of the coal substance, and not—as they should be, and, let us hope, some day will be taken—as elementary constituents of compound constituents.

Every classification based upon chemical analysis must of necessity be more or less imperfect until we are able to express a percentage of carbon in some such form as—

$$C = mC_1 + nC_2 + lC_3 + \&c.$$

i.e., until we are able to say: So-much of the coal's total carbon occurs in this form, and so-much more in that. Until that day arrives classification of coals must remain purely arbitrary; afterwards it may become so exact as to be less valuable, the number of classes demanded being so large as to defeat the main object of classification.

METHODS OF USING THE AVAILABLE DATA.

A reference to the quantities determined by analysis, either proximate or ultimate, will indicate that they may be used in a great many different

ways to form bases for classification. They have been used, by one worker or other, in the following ways :—

(*a*.) Proximate only—

1. Fixed carbon.
2. Volatile matter.
3. Fixed carbon ÷ volatile matter.
4. Modifications of 3.
5. Fixed carbon ÷ sum of fixed carbon and volatile matter.

(*b*.) Ultimate only—

6. Carbon.
7. Hydrogen.
8. Oxygen.
9. Carbon ÷ hydrogen.
10. Oxygen ÷ hydrogen.
11. Carbon ÷ sum of hydrogen and oxygen.
12. Carbon ÷ sum of oxygen and ash.

(*c*.) Proximate and ultimate together—

13. Carbon ÷ fixed carbon.
14. Various combinations of two or more of the above.

It is evidently impossible, even were it desirable, to find space in such an article as this for details of so many different types of classification. The writer therefore proposes first to make some brief critical remarks upon the various bases themselves, then to give a few notes on one or two particular schemes, and to show a composite picture of those properties of the coals which all such schemes must of necessity take into consideration. It must be clearly understood from the outset that the remarks which follow are merely an expression of the present writer's own opinion, and are quite open to criticism.

Fixed Carbon.—Used alone, this factor gives undue prominence to the non-volatile portion of the coal substance. The so-called fixed carbon is by no means all carbon, and its value depends upon its composition as well as its mass. Both mass and composition vary greatly with the method used for their determination. The use of the FC percentage by itself is therefore unscientific.

Volatile Matter.—This factor, despite the difficulty mentioned when dealing with methods of analysis, is capable of providing a fair classification from the standpoint of the metallurgist, but in any wide range of coals is apt to produce much overlapping. Its analytical demands are most moderate, and in the hands of the German authority Wedding(1) it gave good results, although his assumption that the percentage of volatile yielded and the geological age were definitely related is not warranted by facts.

Ratio of Fixed Carbon to Volatile Matter.—Schemes based upon this ratio include all the good points of the two former methods. The ratio does not, however, take into account the quality of the volatiles. It deals with their quantity only.

Ratio of Fixed Carbon to Fixed Carbon plus Volatile Matter.—This seems to have no advantage over the simpler ratio FC/VM.

Many other modifications of this simple "fuel ratio" (FC/VM) have been suggested, and each, perhaps, has its own peculiar advantages; but, for the coals of higher grade, the simple ratio seems as good as any of them, and is nowadays often used as an auxiliary when the classification is based mainly upon other factors. Each form appears at its worst when dealing with coals of high water content and relatively high volatile matter. Hence

in recent years the ordinary fuel ratio has been modified for use with such coals, and is known as the "split volatile" ratio. In this modified form it is certainly better adapted for use with the lignite group.

Split Volatile Ratio $\left(\frac{\text{Fixed carbon plus one-half volatile matter}}{\text{Moisture plus one-half volatile matter}}\right)$.—This is the result of an attempt made by Dowling(2) to reconcile in one expression the data of both proximate and ultimate analyses, and seems to be decidedly the most reasonable in the case of low-carbon coals. It is sad to think that, as it stands, it is merely a compromise of somewhat empirical nature. Its success in connection with low-grade coals is, however, beyond question, and that success may perhaps be taken to indicate that, somewhere or other, a definite scientific basis for it lies hidden from our ken. The ratio is not in general use for high-grade coals, and there is always a difficulty in satisfactorily determining the "change-over" point when using two separate factors in one classification.

Carbon alone or Hydrogen alone.—In either case undue weight is laid upon the element chosen, and, except as a guide to subsequent use of some other factor, the choice of such a method seems quite unjustifiable. Still less is *oxygen alone* fitted to act as a classification basis. We know almost nothing of its state in the coal, and the figures representing it in the analytical results actually sum all the errors that have been made.

The same objection may be made to the use of oxygen, by itself, as either numerator or denominator of a determining ratio—*e.g.*, O/H.

Ratio of Carbon to Hydrogen.—This ratio includes, in simple form, the two elements which are most important in the coal substance. These elements can be determined simultaneously and with a considerable degree of accuracy; and, as no calculation on to the pure coal is needed to form the ratio, the errors which may be introduced in such a calculation are avoided. "The only serious causes of error likely to occur in the C/H ratio are inaccuracies of moisture-determination, and the presence of carbonates or hydrous minerals in the coal, two of which would probably be observed, and the carbonate, at any rate, corrected for." The ratio has been widely used, and it is perhaps not going too far to say that at present there exists a considerable weight of opinion in favour of adopting it as the *best basis for coal classification.*

It must, however, be looked upon as an imperfect basis, since (1) it rests upon an unwarranted assumption as regards the relative value of carbon and hydrogen, (2) it is too sensitive in one direction, and (3) it totally ignores the possibility of isomerism and its effects.

The fraction C/H, if taken in its strict sense, simply means that the more carbon a coal contains the better it is, and the more hydrogen it contains the worse it is. Nobody will deny that increase of carbon is desirable; but how many will be ready to assert that of two coals of the same class, each with 72 per cent. of carbon, but the one with 6 and the other with only 4 per cent. of hydrogen, the latter is worth 18 marks and the former only 12? As a matter of fact, the second coal would be in almost every way inferior to the first.

The ratio is too sensitive, since, though the average percentage of carbon taken throughout the entire range of coals is well over 70, yet the average percentage of hydrogen is only about 5. Hence, while small deviations in the carbon percentage have but little effect upon the ratio, correspondingly small deviations in the hydrogen—whether inherent in the coal substance or due to errors in analysis—have a very marked effect. This deficiency is all the more serious since we have as yet no means of determining the

relative values of carbon and hydrogen in the ratio. As used, the ratio C/H tacitly assumes that one unit mass of carbon is equal in effect to one unit mass of hydrogen. That this assumption is not warranted is shown when one compares coals with equal carbons but varying hydrogens on the one hand, and, on the other, coals with equal hydrogens but varying carbons. The results strikingly show the limitations of the ratio.

Finally, the isomerism of the coal substance (or of some of its parts) is far too important to be completely ignored. Yet it is ignored in any classification based upon the C/H ratio alone.

As long ago as 1857 this failure of the C/H ratio to differentiate properly between certain well-known bituminous coals was pointed out by Stein(3). Special attention was drawn to the same point by Anderson(4) and Roberts in connection with some coals from Lanarkshire and Stirlingshire. Bone(5) also states that his investigations upon English coals "have brought to light some interesting examples of coals possessing quite different properties, whose elementary compositions are very similar."

This isomerism in coals is sometimes scoffed at as a mere bogy, but it is hard to understand how any one with even a passing acquaintance with modern organic chemistry can for a moment doubt its existence. (It becomes very evident when one attempts to calculate the calorific value from analysis, instead of determining it directly, as one should. As, however, laziness is the only excuse for such a practice, the isomerism, in this particular instance, may prove a help rather than a hindrance.)

To the classifier it presents a real difficulty, and one which is likely to remain with us for many a year to come. Isomers can be satisfactorily examined only when isolated; and quantitative isolation of the isomeric bodies existing in two or more different coals will be difficult always, if, indeed, it ever becomes possible. Somewhat similar difficulties have been overcome in organic work, but the isolation has been made from "mixtures" of the ordinary type; whereas a coal, though often spoken of as a mixture, is in its behaviour much more like a complex solution of the solid type, thus making the isolation problem more difficult still.

Such isolation, however, is not necessary for any ordinary classification purposes, since the physical properties of the coals taken in conjunction with their calorific values sufficiently separate them, even though their C/H ratios may be the same. Here again we have evidence that strictness of classification depends upon the number of distinguishing factors taken into account.

Ratio of Carbon to Oxygen plus Hydrogen.—The denominator here contains two terms, one of which represents an element supposed by some to be detrimental, and the other an element regarded as wholly beneficial. The direct summation of these two terms is therefore mathematically incorrect, unless there exists between them a known relation as regards the quantity sought. Such a relation may exist, but as yet it is absolutely unknown.

Ratio of Total Carbon to Oxygen plus Ash.—This rests upon the assumption that, weight for weight, oxygen is as effective as ash in depressing the heating-value of a coal. To the writer it seems a particularly unfortunate ratio to choose, since it depends upon (1) ash, which is subject to considerable errors in determination, and (2) oxygen, which at present can be determined by difference only. It most certainly is not true that *all* the oxygen in a coal is valueless, and, even if it were, surely the hydrogen is of some value! The ratio C/(O + A), however, ignores one of the two most useful elements in the coal, and concentrates its attention upon those portions which it supposes to be merely useless load. Recording a person's

defects is not necessarily an exact method for arriving at a true estimate of his value to the community. An efficiency curve based upon this ratio cannot be expected to follow closely the curve of determined efficiencies. This was seen by White(6), the proposer of the ratio, and in his article on its use he attributes the most marked deviations to the " percentages of those elements that have been ignored as negligible constants—hydrogen, sulphur, and nitrogen." It may be permissible to ignore both sulphur and nitrogen in dealing with the coals of a restricted area, but to treat hydrogen as a negligible constant is altogether unjustifiable, since the influence of extremely small changes in the hydrogen percentage is generally most marked.

Ratio of Fixed Carbon to Total Carbon.—This requires both ultimate and proximate analyses. It is true that it makes use of the carbon only of a combustion analysis; but, as it is just as easy to determine both carbon and hydrogen as carbon alone, and the numerator is not comparable with the denominator in exactness of determination, it cannot be considered so satisfactory as those ratios which depend entirely upon the more exact method of analysis. As used by Grout(7), however, it has given methods of grouping and of graphing which deserve more notice than they seem to have attracted.

THE THREE MAIN GROUPS OF COALS.

It will be convenient at this point to summarize briefly the prominent characteristics of the three great groups into which all ordinary coals are now divided—namely, anthracites, bituminous coals, and lignites.

The *bituminous* group, at once the most important and the worst-named of the three, may be taken first. Broadly speaking, the term " bituminous " is applied to a series of " flaming " coals, chiefly of Palaeozoic or Mesozoic age, carrying relatively little water of composition, and containing in the coal substance about 84 per cent. of carbon on the average. In all modern classifications they lie between the lignites and the anthracites.

The bituminous group includes the " sea-coles " and the " pit-coles " of early days, and, to the people of Great Britain, the best " household " coals. (The household coals of a large portion of New Zealand are lignites, while until quite recently *the* household coal of the United States was anthracite.) The name " bituminous " is said to have been given to these coals because as a group they soften or appear to undergo a partial fusion when heated to a temperature far below that at which actual combustion occurs. " The term is based upon a misunderstanding of the nature of the occurrence, since, although the softening takes place at a low temperature, still it marks the place at which destructive distillation begins. That nothing analogous to bitumen exists in the coals is proved by the fact that the ordinary solvents for bituminous substances, such as carbon bisulphide and benzole, have no effect upon them, as would be the case if they contained bitumen." The last two sentences are taken from the *Encyclopaedia Britannica* (ed. 9, vol. 6, p. 45; and also ed. 11, vol. 6, p. 575) in order to illustrate the general ideas concerning the coals. They are certainly less bituminous than some of the lignites; and it is still uncertain whether the apparently bituminous substances contained in them are definitely related to the real bitumens. For both these reasons the name applied to them is unfortunately chosen; but it was chosen long ago, has been in almost universal use ever since, and, though perhaps with some slight modification, will remain as long as coals are available. After all, in the matter of nomenclature priority has some claims, and where both priority and world-wide usage agree it would be unwise to make any attempt at radical change until very strong reasons for such change are forthcoming. The statement quoted above that bituminous coals are not attacked by solvents such as carbon bisulphide and benzole is not strictly true. Many coals of the group are capable of yielding considerable amounts of extracted matter to benzole. Here, as elsewhere in the behaviour of coals, it is all a matter of quantity. The explanation of the term " bituminous " given above is by no means the only one. It is indeed far more likely that the odour and general character of the volatile portions given off by such coal when heated provided the reasons for calling it " bitumen lapideum."

The *lignitic* group includes nearly all the coals which may be said to be of lower grade than the bituminous coals; the *anthracitic* group nearly all those of higher grade than the bituminous coals. The lignites are characterized as a group by comparatively high water content, and average about 73 per cent. of carbon. The anthracites carry very little water, and contain about 93 per cent. of carbon. Further, the ratio between the volatile matter and the fixed carbon of the coal decreases steadily as we pass from the lignitic, through the bituminous, to the anthracitic group.

If any coal is so inconsiderate as to decline a position in one of these three main groups it is either pushed into one of the neutral territories (transition groups) placed between them, or said to be an abnormal coal. This general practice, though undoubtedly convenient, is simply an acknowledgment of the fact that our classifications are still imperfect.

The accompanying diagram, showing the relative positions of the group members, considered as made up of an energy-producing portion (the so-called coal substance) and a load to be carried (namely, water and ash), may make the position somewhat clearer to those not familiar with the three kinds of coal. The coals used for the purpose of the diagram are real coals, but the lignite (L) is not quite so high in its group as the bitumite (B) and the anthracite (A) are in theirs.

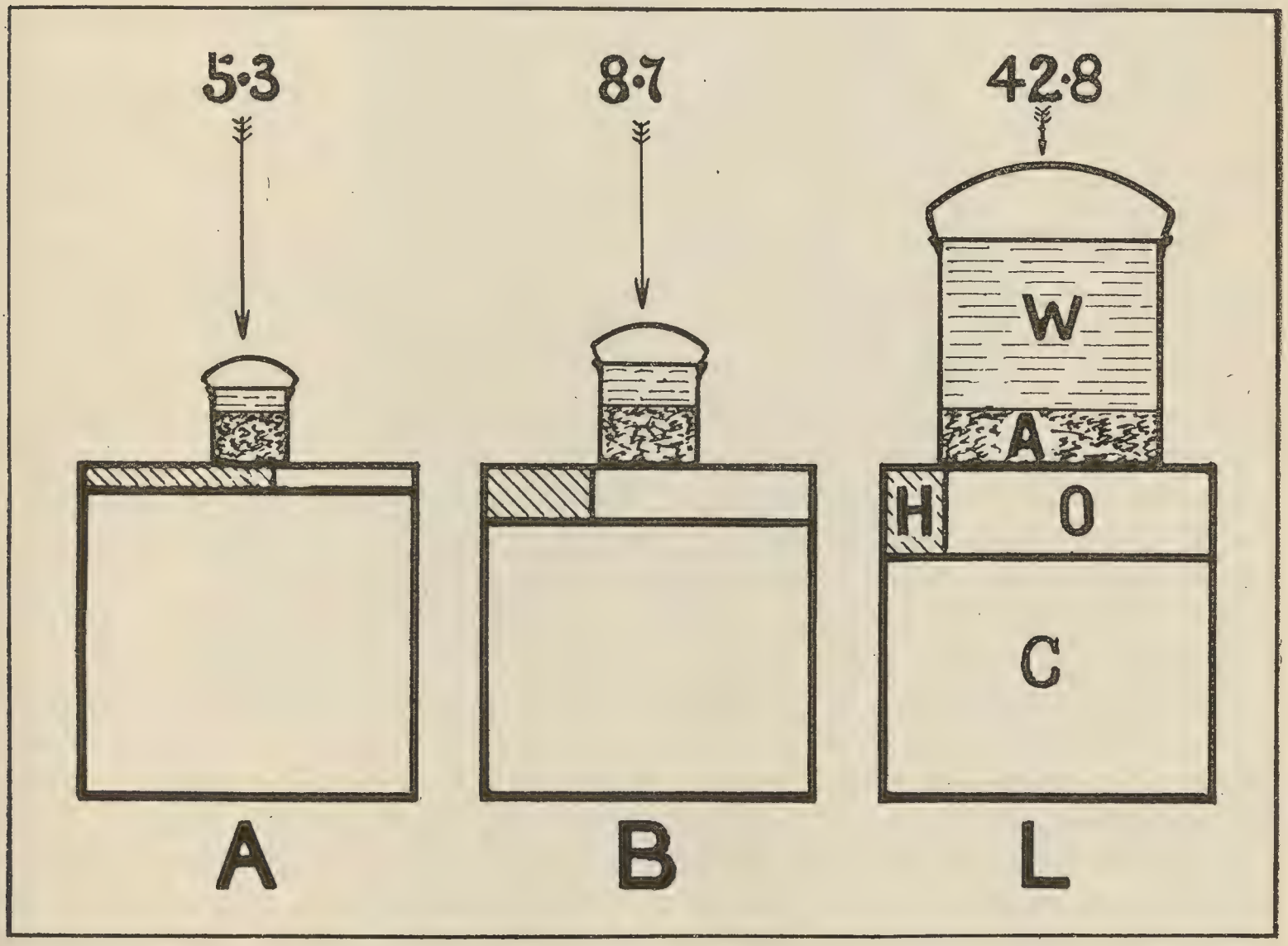


DIAGRAM SHOWING LOAD (WATER AND ASH) CARRIED BY 100 PARTS COAL SUBSTANCE OF A TYPICAL COAL FROM EACH OF THE THREE MAIN GROUPS.

The division of the coal substance into carbon, hydrogen, and oxygen, and the relative proportions of water and ash, in the load are indicated, as well as the total loads. The calorific values (net) of the three coals illustrated are 7960, 7850, and 5780 respectively. A comparison between these calorific values and the ratios load: coal substance clearly shows that the gross heating-value of the coal substance of the lignite must be large in order to bear the heavy load and yet have heat energy to spare.

A rough calculation—and it can be rough only in such a case—shows that the calorific value of the true coal substance in the case of the lignite here illustrated is slightly higher than that of the anthracite, and only a little less than that of the bitumite.

In rounded figures, the three coals in the diagram have the composition following (sulphur omitted) :—

	Raw Coal, per Cent.		Coal Substance, per Cent.		
	Water.	Ash.	Carbon.	Hydrogen.	Oxygen.
A	1·8	3·2	94·0	3·5	2·5
B	3·5	4·5	84·0	5·5	10·5
L	22·5	7·5	74·0	5·0	21·0

TYPICAL CLASSIFICATIONS, OLD AND RECENT.

Classification, even of the type now under consideration, is by no means a child of this century. The first scheme to which any reference will be made is that of Regnault(8), which itself dates from 1837. Regnault found that the percentage of carbon, and of oxygen in particular, "could be used to group the coals in such a manner that their utility for different industrial operations was indicated, and suggested five classes" — namely, (1) anthracites; (2) fat hard coals; (3) fat soft coals; (4) fat coals with long flame; (5) dry coals with long flame.

He saw very clearly that there existed no fixed line of demarcation between the different classes, for he says, "Il est inutile de dire qu'il n'existe aucune séparation nette entre ces divers genres, il y a au contraire passage insensible de l'un à l'autre."

This classification of Regnault's was really based upon determinations of carbon and hydrogen—Regnault was, in fact, the first to make accurate ultimate analyses of coals—for the oxygen, used as a partial basis, was obtained by *difference only*. It was far ahead of previous schemes, and formed the foundation of many subsequent ones, notably that of Gruner(9), Vice-President of the French Council of Mines, which has been more quoted, and misquoted, than any other of its kind. Gruner, in his modification, made a very successful attempt to serve both science and industry, in this point, as in most others, following closely the lines of his model. The joint scheme is often called after Gruner alone, but should be known as the Regnault-Gruner classification—as is, indeed, becoming more and more the custom. It makes use of physical characteristics, ultimate analysis, and the results of coking trials. It depends, however, upon the last of these factors far more than is at first sight apparent, and is in reality a semi-technical classification. It has been criticized much, and by many; but the gist of all that has been written about it may, in the present writer's opinion, be summed up as follows: The classification is a good one; it must have been extremely useful to those for whose use it was primarily made; we also have used it with advantage; but, after all, it does not suit the coals from such-and-such a mine, or those for which we ourselves are making a special classification. Many of the criticisms are quite justifiable; some are evidently the result of national jealousy. Those that are justified by the facts will be equally applicable to nine out of ten schemes of the kind.

This classification will be found, in many modifications, in English, American, and German works: for instance, as modified by Brame, it is

given on page 48 of *Fuel* (ed. 2); as modified by Bone, it appears on page 64 of *Coal and its Scientific Uses* (ed. 1)—the name in each case being given as Gruner. Sometimes it is actually called a German classification, probably because, appearing almost at the same time in France and Germany, it became more widely known in translations from the German version. Muck(10), who used it comparatively early, always correctly gives Gruner.

The author of this historical modification of the Regnault classification was Louis E. Gruner, Inspector-in-Chief of Mines for France, and some time

FIG. 2.—Lignite (N.Z.)—water, 16 per cent.—showing almost micaceous fracture. Owing to the high light the fracture resembles that of bird's-eye cannel, but the coal has not the properties of a cannel.

Professor of Metallurgy, first at St. Etienne, and afterwards at the Paris School of Mines. His first paper on calorific values was read in 1855, and the second, including the classification, in 1873. His greatest work was a survey of the geological relations in the coal-basin of the Loire, which embodied the results of observations extending over forty years. He was undoubtedly one of the greatest of European metallurgists, a man of fertile and intensely active mind, and, if one may judge from the verdict of his pupils, as kind as great. These few notes are added because so much confusion appears to exist regarding the man and his work.

The most serious difficulty in the way of any classification making coke-yield a principal factor is that the yield may vary between such wide limits while the coke itself is almost constant in kind. This tends to bring coals of very different sorts into one and the same group, and was noted by Muck as long ago as 1881.

It may be of interest to note that the same scheme, though very much amplified and improved, was used by E. Gruner and G. Bousquet(11) in the *Atlas général des houillières* as recently as 1911. The present commercial classification of the Saar and Westphalian coals (lignites excluded) is but a further modification specially suited for definite coal groups. These later variations on the original Regnault-Gruner scheme naturally take into consideration new factors, improving generally as their horizon widens.

Another early classification which has been used as the basis of many more modern and, in some ways, more ambitious ones is that advanced in 1849 by the Englishman, J. Field. Field(12) also gave five main groups, using the names " bituminous," " semi-bituminous," " partially bituminous," " anthracitous," and " anthracite." His classification was based upon proximate analyses of about two hundred coals from South Wales, the factors involved being volatile matter, fixed carbon, and ash. Field's classification is usually looked upon as the direct " basis of that put forward by Rogers(13), (1858) in his classic on the coalfields " of England and the United States.

These two older classifications are put prominently forward here in order to show how much all modern workers upon coal are indebted to those of previous generations, sometimes to those whose good works are almost forgotten.

Typical—one ought rather to say, quite the best—of the more recent classifications, which it will be remembered show a marked tendency to use the C/H ratio as the main factor, is that of Seyler, published in 1900. Seyler(14) " studied in particular the coals of South Wales, and confirmed Regnault's statement that the typical classes of coals fall within narrow limits of ultimate composition." " For coals containing *less* than 84 per cent. of carbon the percentage of carbon alone " is first used. " These coals constitute the lignitious ' genus ' (corresponding with the ' dry long-flame ' coals of Gruner's classification), which is subdivided into his so-called ' species ' (per-lignitious, lignitious, and sub-lignitious) according as the hydrogen content is high or low. When the coals contain *more* than 84 per cent. of carbon, the hydrogen percentage is the chief factor determining the character of the coal, and five ' genera,' each subdivided into ' species,' are distinguished."

So far there is no mention of the C/H ratio ; but, as Seyler first divides the high-grade coals into genera by means of the hydrogen content, and then divides each genus into species according to the carbon content, it is evident that his classification is based upon (1) the hydrogen, and (2) the carbon to hydrogen ratio, although the rectangular-field method used avoids, by means of its linear boundaries, one of the main difficulties attending the direct use of simple ratio values. (This point will be explained later when dealing with diagrammatic representation.)

" The use of the words ' genera ' and ' species ' for kinds of coal is obviously to be deplored, since the coal mass was formed of actual biological genera and species which bear no relation to the resulting kinds of coal." The chemist might also complain of the use of the well-known prefixes " meta," " ortho," and " para " in connection with organic substances whose constitutive relationships are totally unknown.

FIG. 3.—Lignite (N.Z.)—water, 27·5 per cent.—showing normal fracture and incipient weathering cracks.

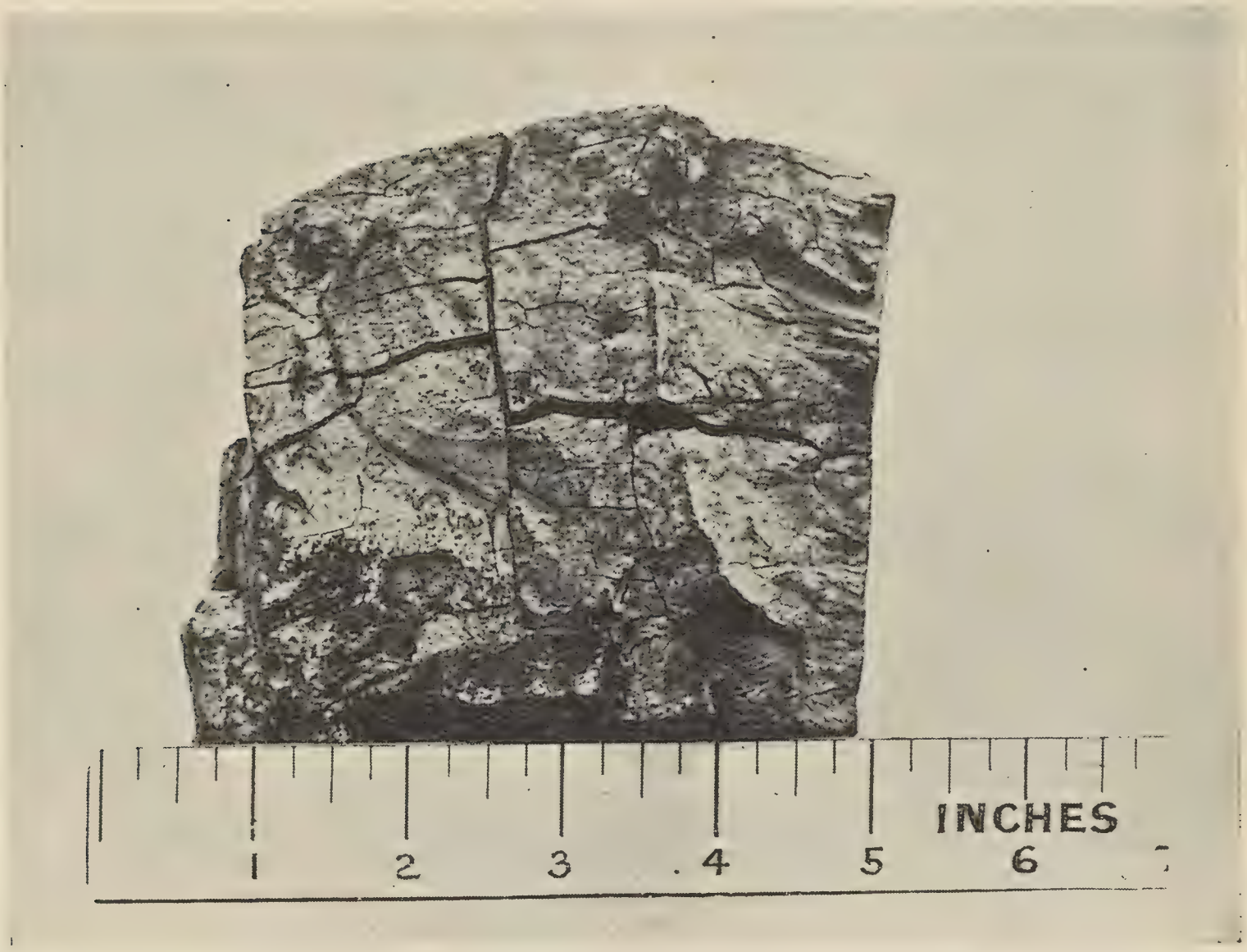


FIG. 4.—Lignite (N.Z.)—water, 27·5 per cent.—showing weathering cracks after five years' exposure.

As the original classification was made for coals containing relatively large proportions of carbon, the lower limit assigned to that element is 75 per cent. Most members of the true lignite group are therefore excluded. In a diagrammatic form, extended and somewhat modified, it will be used in connection with New Zealand lignites in order to show their position relatively to the older coals of Wales. The full classification may be found in the appendix to the monograph of Stopes and Wheeler, already quoted, together with a considerable amount of concisely written explanatory matter, from which the quotations marked above have been taken.

Seyler's classification formed the basis of that used by Strahan and Pollard(15) in their exhaustive survey of the coals of South Wales, although they finally determined to use the ratio C/H directly, instead of indirectly, as the principal determining factor.

What is really the same classification, though based upon quite independent work, and therefore a valuable testimony to the correctness of Seyler's scheme, has been adopted in many cases by the United States Geological Survey(16). This classification, which is based directly upon the ratio of C/H, extends beyond that of Seyler, taking in graphite on the one hand, and the lignites, peat, and wood on the other. Omitting what may be called the limiting forms of graphite, peat, and wood, the true coals are divided into anthracites, semi-anthracites, semi-bituminous coals, bituminous coals (four subdivisions), and lignites. The C/H ratio, 11·2 to 9·3, is assigned to the lignites.

A SUGGESTED CLASSIFICATION FOR USE WITH NEW ZEALAND COALS.

For some years past the writer has found difficulty in making clear to students and others the signification of the different names applied by different classifiers to the different kinds of coal in common use. Gradually he has been forced to refer them all to some standard, and in such gradual manner the system here outlined has grown. There is very little in it that is original—it is, in the main, nothing but a simplified and partly extended form of Seyler's system adapted to local conditions. The different groups are not strictly divisible one from the other, and the nomenclature adopted may be criticized; but that is to some extent at least consistent, and certainly not worse than the average nomenclature.

Firstly, coals are divided into two families:—

I. The *ordinary coals*—apparently, for the greater part of their mass, non-sapropelic.

II. The *special coals*—for the most part definitely sapropelic.*

The first family includes the so-called "humic" coals; it is, indeed, so largely made up of them that it might be called the "humic family."

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* These coals are generally supposed to owe their distinctive character to (1) the "special" nature of the organic mass from which they developed, and (2) the "special" conditions under which that mass was laid down. They are essentially rocks derived by processes of solidification and partial oxidation from water-laid deposits consisting entirely—or at least largely—of plant-spores and pollen-grains, together with the more or less comminuted remains of low orders of water plants and animals. The term "sapropelic" we owe to Potonié. "On the floors and surface of some lakes to-day there is accumulating a substance which he called 'sapropel.' This is a gelatinous mass or slime which results from the former plankton, both animal and vegetable, partly decomposed or putrefied in quiet or stagnant water. Potonié believes that in cannel coal we are dealing with a fossil sapropel. He terms any rock in which sapropel forms a considerable part a 'sapropelite.'" (Naturally, these sapropelites are not always coals. Potonié further divides the carbonaceous sapropelites according to their age, but this subdivision does not affect any ordinary classification.)

FIG. 6.—Bitumfte (N.Z.) showing conchoidal fracture as a dominant characteristic.

FIG. 5.—Bitumite (N.Z.) showing normal fracture.

As, however, the word "humic" is used in several different senses, the expression "non-sapropelic" seems preferable, quite apart from the fact that it is wide enough to include coals which, though they may not be humic, are evidently not sapropelic. Such at least is the supposed division into families; but, as the terms "sapropelic" and "non-sapropelic" imply definite conditions regarding the manner in which the coals were formed, and the existence of such conditions cannot in general be definitely proved, the two families may preferably be alluded to by number only, or as "ordinary" and "special."

The coals most familiar to the people of this Dominion belong to the "ordinary" family, though some smaller masses of coal seem to belong definitely to the "special" or "sapropelic" family.

The "ordinary" family is divided into three main groups—lignites, bitumites, anthracites. On each side of each main group is situated an attached group; the two between the lignites and the bitumites forming one transition group, and similarly the two between the bitumites and the anthracites another transition group. We thus arrive at the scheme outlined in Table I.

LIMITING VALUES FOR CARBON AND HYDROGEN.

These are based directly upon those given by Seyler for the ortho-sections of his classification. The value for the lower limiting carbon percentage in the ortho-section of the lignitious coals of Seyler has, however, been raised from 75 to 76 in order to give a wider range to the main lignite group of the modified scheme. For the same reason the hydrogen limits for the normal members of the group have been set at 4·5 and 6 instead of at 5 and 5·8; for, although the hydrogen average for the lignite group is somewhat lower than that for the bitumite group, yet the range of hydrogen percentages is considerably wider in the normal lignites than in the normal bitumites. The hydrogen limits of the high-carbon coals have been slightly altered, and the typical anthracites restricted to the 93·3 and 95·5 carbon lines. The carbon limits of the scheme are to be considered as fixed; but the hydrogen percentages given are in each case those of the normal coals only. Coals with higher and lower percentages of hydrogen occur in most groups, and their carbon content practically determines their position.

NOMENCLATURE.

(1.) The expression "bituminous coals" is shortened to the one word "bitumites." As the coals are rocks, there can be no formal objection to the termination "ite," especially as it has been so long in use in the names "lignite" and "anthracite." "Bitumite" is also so close to the time-honoured "bituminous" as to avoid the risk of confusion with other class-names.

(2.) The term "humic" is used to include *all* humic coals. It is therefore applied to lignites—and, if need be, to anthracites—as well as to bitumites. The writer thinks that it should be so applied, if used at all. The common restriction of the term to the bituminous coals seems scarcely more defensible than the proposal to substitute "humic" for "bituminous" as a group-name. "Bituminous" is no doubt a misnomer, but that is hardly a sufficient reason for abandoning it in favour of another name which in one of its meanings is not more applicable to the bitumites than to many other coals, and in its other well-recognized meaning very much less so than to the lignites.

TABLE I.

Families.	Groups.		Group Symbol.	Normal Limiting Values (Coal Substance).		Ratio $\frac{C}{H}$	
	Main.	Transition.		Carbon, per Cent.	Hydrogen, per Cent.	Normal Range.	Average Value.
I. ORDINARY COALS .. (For the greater part of their mass apparently NON-SAPROPELIC)		Sub-lignites ..	Lb	Under 65	4·5 to 6	Under 14·4	(?)
	LIGNITES ..	..	L	65 to 76	4·5 to 6	10·8 to 16·9	13·8
		Super-lignites ..	La	76 to 80	5 to 5·8	13·1 to 16	14·5
		Sub-bitumites ..	Bb	80 to 84	5 to 5·8	13·8 to 16·8	15·3
	BITUMITES ..	..	B	84 to 89	5 to 5·8	14·4 to 17·8	16·1
		Super-bitumites..	Ba	89 to 91·2	4·5 to 5·3	16·8 to 20·2	18·5
		Sub-anthracites	Ab	91·2 to 93·3	4 to 4·8	19 to 23·3	21·1
	ANTHRACITES..	..	A	93·3 to 95·5	3 to 4	23·3 to 31·8	27·5
		Super-anthracites	Aa	Over 95·5	Under 3	Over 31·8	(?)
II. SPECIAL COALS .. (For the greater part of their mass evidently SAPROPELIC)	LIGNITIC ..	..	Sλ	Under 80	Over 6	Under 15	(?)
	BITUMINOUS ..	..	Sβ	80 to 91·2	Over 6·5	Under 14	(?)
	ANTHRACITIC ..	..	Sα	(Over 91·2)	(?)	(?)	(?)

(3.) The prefixes "sub" and "super" are used consistently. They are, perhaps, not so expressive as could be wished, for they do not emphasize sufficiently the closeness of relationship existing between the sub- and super-sections and the main groups to which they are attached. They do, however, clearly indicate that the sub-bitumites (for instance) are of lower grade, and the super-bitumites of higher grade, than the coals of the main bitumite group. Moreover, the use of them as indicated entirely does away with the ambiguity at present attaching to the indiscriminate use of the prefixes "semi," "sub," and "per." The prefix "semi" is in itself quite useful, but in the case of a coal classification it cannot be used consistently. If an attempt be made to use it throughout the system we necessarily arrive at *two* attached "semi-bitumite" groups, or *two* attached "semi-groups" for the middle one of the three main groups, whatever name be given to that main group. The word "semi-anthracite" is also somewhat too mathematical in suggestion to meet the case of a coal which is far more nearly a "nine-tenths anthracite."

(4.) The family names are open to more serious objection. However, in the present state of our knowledge similar objection could be raised against any descriptive names. Hence, as the term "sapropelic" is not too restricted, and seems to have taken firm root in the ground of coal literature, it has been adopted. The other family name, "non-sapropelic," stands or falls with it.

(5.) The class symbols are, in the case of the main groups, simply the initial letters of the group-names. This seems preferable to the use of A, B, and C. If A be used for the anthracites, it conveys the impression that they are the best; while—as is well known—though good, they are yet not best in the eyes of all users of coal. The derived symbols for the subgroups at once show the positions of the small bodies to which they belong: "*a*" naturally implies above, and "*b*" below. The coals of the "special" family are all given the letter S, the subdivisions being indicated by the affixed λ, β, and α.

(6.) Objection may be made to dividing the coals into two families on the ground that they are all members of one rock-series. However, when an attempt is made to show their general relationships in ordinary tabular form, separation of some sort is convenient, if not absolutely necessary. A lignitic cannel, if considered as a canneloid-lignite, may reasonably be looked for among the lignites. Unfortunately, its high hydrogen content and special properties put it in a special position of its own. It therefore becomes necessary either to make special subdivisions in the lignite and bitumite groups for canneloid-lignites and canneloid-bitumites respectively, or to put all such canneloids in a "special" family of their own. For many reasons the writer thinks the latter course preferable.

A COMPOSITE PICTURE SHOWING GENERAL CHARACTERISTICS OF FAMILY 1.

The tabular statement inserted (Table II) gives a number of details with reference to the "ordinary" family of coals. The "bitumite" and "anthracite" sections, however, are filled in only so far as seems necessary to show their relationship to each other and to the lignites. In order to avoid further complication of the table, and also because they can but represent either the ideas of a particular individual, or the average of a number of similar figures taken from various classifications, figures have as far as possible been omitted from the columns under "Chemical Characteristics." This point will be referred to later.

(To be continued.)

Varieties.	Some of the Names used in various Classifications (English and American) for similar Groups and Varieties (Local Names not mentioned).	
..		
Fibrous Lignites	Xyloid lignites Brown lignites	Brown coals. Hydrous coals.
Earthy Lignites	Lignites	
Slaty Lignites	Black lignites Lignitic coals	
Conchoidal Lignites	Sub-bituminous coals	
..	Ligno-bituminous coals.	
..	Lignitious coals Low-carbon bituminous coals Per-bituminous coals (in part)	
Arbitrarily divided into varieties; usually by carbon and hydrogen content and (or) nature of coke yielded	Humic coals	
..	Semi-bituminous coals High-carbon bituminous coals Pseudo-carbonaceous coals	Anhydrous coals.
..	Semi anthracites Carbonaceous coals	
..	Graphitic coals	

[*Face p. 170.*

TABLE II.—SHOWING THE GENERAL CHARACTERISTICS OF THE MAIN GROUPS, AND, IN THE CASE OF THE LIGNITES, OF THE GROUP DIVISIONS.

Group Symbol.	Groups. Main.	Groups. Transition.	Physical Characteristics. Origin.	Texture.	Colour.	Lustre.	Cleavage.	Weathering Cracks.	Specific Gravity.	Hardness.	Chemical Characteristics. Water per Cent. as mined.	Percentage Composition of Coal Substance (excluding Sulphur) C.	H.	N.	O.	Ratio. C. H.	Ratio. F.C. V.M.	Calorific Value. Gm-Cals./Gm.	Action of Nitric Acid.	Solubility in Phenol.	Apparent Acidity.	Coking-quality.	Varieties.	Some of the Names used in various Classifications (English and American) for similar Groups and Varieties (Local Names not mentioned).
Lb	..	SUB-LIGNITES ..	..	..	..	..	..	..	..	..	..	Under 65	4·5 to 6	..	..	..	..	..	Maximum			..	..	
L	LIGNITES ..	..	Fairly evident on inspection in nearly all cases	Loose | Fibrous — Soil the fingers on handling; earthy marks	From yellow through browns to greenish-black	Dull and earthy; no true lustre except where coal covered with oxide-film	Markedly irregular; changes of direction abrupt	Go right through coal; often following lines of woody structure. Irregular	0.5 to 1·35	—— Increasing gradually towards the anthracites, where the hardness attains a maximum (approximately 2·5 mohs.) ——	Varying from 1 to over 60, but usually between 8 and 40. Variation independent of variety: *e.g.*, an earthy lignite may have but 5 per cent., while a hard conchoidal may carry 40	65 to 76	4·5 to 6	Very variable, and through a wide range in the lignite group. Average value about 1·3	—— Decreases gradually from lignites to anthracites ——	Increasing from lignites to anthracites; coals of same group, but from different districts, show considerable differences in the ratio, especially lignites	—— For the group, as a whole, less than 1 ——	—— 4,000–7,700 —— Increasing from lignites (rapidly at first) to a maximum in the bituminites of high carbon and high hydrogen; thence falling	All three factors decrease gradually from the lignites to the anthracites. For instance, while many of the fibrous and earthy lignites are completely disintegrated by nitric acid within a few hours, the conchoidal lignites are much more resistant, the bituminites still more so, and the anthracites, as a whole, are hardly affected at ordinary temperatures		As a group, non-coking; though many of the higher-carbon lignites give a fairly good porous coke	FIBROUS LIGNITES EARTHY LIGNITES SLATY LIGNITES CONCHOIDAL LIGNITES	Xyloid lignites Brown lignites Lignites Black lignites Lignitic coals Sub-bituminous coals Brown coals. Hydrous coals.
			Less evident on inspection	As a rule do not soil the fingers on handling	Dark grey, and through brown to almost black	Dull	Slaty; laminated; fracture across bedding-planes often conchoidal	Often hardly noticeable; short and straight																
					From very dark brown to the black of a bituminite	Greasy; often distinctly pitchy	More or loss conchoidal; curves sometimes of short radius	Curved; not widely opened, and often forming very slowly																
La	..	SUPER-LIGNITES ..	..	..	..	..	..	..	..		..	76 to 80	5 to 5·8	..		..	..					..	..	Ligno-bituminous coals.
Bb	..	SUB-BITUMITES ..	..	..	..	..	..	..	..		..	80 to 84	5 to 5·8	..		..	..					..	..	Lignitious coals Low-carbon bituminous coals Per-bituminous coals (in part)
B	BITUMITES ..	..	Not evident on surface inspection, but distinctly shown in thin sections under the microscope	Compact; generally soil the fingers; black and sooty marks	Very dark grey to black	Varying from earthy to highly resinous	Generally distinctly prismatic; parallel and at right angles to the bedding-planes	Not apparent in general, unless the coal has been exposed under very abnormal conditions	1·15 to 1·55		Varying between 0·05 and 20, but usually between 0·2 and 12	84 to 89	5 to 5·8	Average 1·5 —— No great variation in either of these two groups ——			—— For these two groups, greater than 1 ——				As a group, coking; nature of coke varying with chemical constitution of coal	Arbitrarily divided into varieties; usually by carbon and hydrogen content and (or) nature of coke yielded	Humic coals	
Ba	..	SUPER-BITUMITES ..	..	..	..	..	..	..	..		..	89 to 91·2	4·5 to 5·3									..	..	Semi-bituminous coals High-carbon bituminous coals Pseudo-carbonaceous coals Anhydrous coals.
Ab	..	SUB-ANTHRACITES ..	..	..	..	..	..	..	..		..	91·2 to 93·3	4 to 4·8										..	Semi anthracites Carbonaceous coals
A	ANTHRACITES	..	Not evident, but in many cases shown in micro-sections	Do not soil the fingers	Iron-grey to black	Varying from dull to brilliant and sub-metallic	Very variable; cubic, hexagonal, conchoidal, micaceous	Not apparent in general, unless the coal has been exposed under very abnormal conditions	1·25 to 1·7 (extreme cases 1·9)		Varying between 0·2 and 6	93·3 to 95·5	3 to 4	Average 1·0 —— No great variation in either of these two groups ——			—— For these two groups, greater than 1 ——				—— Non-coking ——		
Aa	..	SUPER-ANTHRACITES	..	..	..	..	..	..	..		..	Over 95·5	Under 3	..		..	..		Minimum			..	..	Graphitic coals

CRETACEOUS AND TERTIARY FORMATIONS OF NEW ZEALAND.

THE UNCONFORMITY BETWEEN THE CRETACEOUS AND TERTIARY FORMATIONS OF THE EAST COAST OF THE NORTH ISLAND.

By M. Ongley, M.A., B.Sc.

(Continued from page 117.)

Just as the fossils below the conglomerate found in the Waipara by Marshall showed that the Tertiary extends below it, so the Tertiary fossils (*Glycymeris*) on Waitangi Hill show that there are some Tertiary rocks there, as has been recognized by all geologists.

The East Coast Unconformity.

Standing on the hills west of the Waipaoa River or its tributary Wairangiora, in Arowhana or Tutamoe Survey District, and looking eastward, one sees a striking difference between the higher and the lower country. In the background one sees the flat table-top of Tutamoe with its vertical cliffs; in the foreground there are rounded smooth and hummocky hills with landslip topography. So striking is the difference in topography that McKay in 1874, looking at Tutamoe Ridge from Waitangi Hill, some seven miles away, was able to recognize it as Tertiary. But not only is the difference in topography striking; an observer looking eastward toward Tutamoe Table cannot miss the colour contrast—light below, dark above—corresponding with McKay's chalk-marls and *Leda* marls respectively, or the Awanuian (Cretaceous) and the Ihungian (Tertiary) of this report. In the attempts made to photograph this the colour contrast was largely diminished by over-exposure, yet it may be made out in the three photos (figs. 1, 2, 3). The colour contrast is marked throughout the district, and is conspicuous even where there is only a thin remnant of Tertiary mudstone, as in the head tributaries of the Makarika and in Waipiro Stream. It is plain, too, in the upper Reporua Stream, and over the hill near the Waiapu, in Whakoau Stream, and along the valleys of the Poroporo and Maraehara, in the last of which was taken the view appearing in fig. 3.

The topographic and colour differences are due to rock differences, and it may yet be said that the rock differences are due not to an erosion interval or an unconformity but to different beds.

On Pipe D Hill, south-east of Wairangiora-Waimatau junction, shown in fig. 1, the top is formed of grit and conglomerate beds. The pebbles in the conglomerate are mostly dark igneous, and greywacke, with a few light igneous stones up to 2 in. in diameter, but generally finer, smoothly rounded and polished; among these are rare pieces of chalky limestone and light mudstone. The conglomerate is about 100 ft. thick. Below it are several bands of coarse sandstone, forming the upper part of the cliff shown in the view. As shown there, dark arenaceous unbedded mudstone forms the cliff-face for 120 ft. in the vertical upper part, and overlies well-bedded, fractured, white argillaceous limestone, affording a marked colour and rock contrast. Along the contact the tutu-bushes grow more

luxuriantly; and at the actual contact is a $\frac{1}{2}$ in. to 2 in. band of soft crushed red clay, and in places a 3 in. band of limestone-fragments. The cliff-face is not easily accessible, and it is difficult to get convincing observations of strike and dip, but the light beds are contorted below and appear to be truncated at the contact. Still, as the bedding-planes are obscure near the contact this cannot be demonstrated. Further, the white formation lower down, at the foot of the cliff, is standing nearly vertical in many places in short contorted folds, so that the evidence for unconformity is irresistible.

The contact can be followed from this outcrop eastward and westward along the spur for about 20 chains, and north and south along the Waipaoa, or near it, for some seven miles, and was examined at many points. In

FIG. 1.—Tertiary beds above, Cretaceous below, on south-west of Pipe D Hill, Tutamoe Survey District.

Island Creek, which flows west into the Waipaoa, half a mile to the south, the contact is as follows: In the lower part of the stream are folded, contorted, fractured, thin beds of bluish, white, and greenish, dense, fine siliceous mudstone, with some bands of ripple-marked sandstone and some crushed bands of blue mudstone affording numerous outcrops. These stand steep, and strike and dip variously, indicating complex folding, but have a regional dip to the south-east, so that in going up the creek one rises on the strata. The hard light bands dip towards a crush-zone in which there is no solid rock, but only pieces of crushed mudstone and calcareous sinter. This forms the creek-sides for the next 13 chains, and across it we find one outcrop of the light crushed and shattered dense rock which dips below a band of grit with $\frac{1}{2}$ in. pebbles of the white bed. Above this lie many bands of grit and conglomerate in the following sequence: 4 ft. of blue mudstone striking 145° and dipping east 40° is unconformably overlain by 20 ft. of conglomerate with 2 in. pebbles which strikes 185° and dips east 70°. Above

this is 25 ft. of sandstone, 4 ft. of mudstone, 2 ft. of sandstone, 10 ft. of mudstone, 1 ft. of conglomerate, 6 ft. of conglomerate and sandstone, 12 ft. of arenaceous mudstone and conglomerate, 3 ft. of sandstone, 6 ft. of sandstone and conglomerate, 15 ft. of mudstone and conglomerate, 6 ft. of sandstone and conglomerate, 3 ft. of mudstone and conglomerate, 40 ft. of conglomerate in sandstone matrix, 6 ft. of coarse conglomerate with well-smoothed pebbles up to 6 in. in diameter of chalky limestone, white shale, dense white siliceous mudstone, fine sandstone, and gabbro. This coarse conglomerate strikes 180° and dips west 80°, and half a chain west strikes 95° and dips south 40°. Four chains more of slumping mudstone obscures the sides, and east of that we have the dark grey-blue arenaceous mudstone with thin bands of sandstone striking 5° and dipping east 70°. Farther east there are some more breaks and contortions, but the beds generally are mudstone with a few grit bands and Tertiary fossils, and the table-top of Tutamoe caps the whole.

This section is so broken and complicated that it may be objected to, but does it suggest uninterrupted sedimentation or elevation and erosion ?

One and a half miles farther south in Malau Creek, and three and a half miles farther south in Mag Creek, the contacts were examined. In Malau Creek there is so much slumping crushed mudstone that no good section can be seen, but the rock contrast is characteristic, and the basal Tertiary bed seen is shell rock with small igneous pebbles similar to another outcrop a mile north of Pipe D Hill. In Mag Creek the exposures are as shown in fig. 2. The rock contrast is characteristic. Below are crushed white mudstone and limestone; at the erosion interval, on the north side, is 6 in. of crushed mudstone; above it are 1 ft. of sandstone, 2 ft. of mudstone, 6 in. of sandstone, 3 in. of mudstone, 1 ft. of fine conglomerate. On the south side are bedded conglomerates included in the mudstone and sandstone; the pebbles in the conglomerate are gabbro, greywacke, some limestone, and some soft mudstone from the beds below. Still farther south, in the Mangaorongo, the shattered and crushed Awanui (Cretaceous) white mudstone, bluish mudstone, white mudstone, and limestone in the bed strike 115° and dip north 50°; 300 ft. up the cliff to the north, at the contact, the Ihungia (Tertiary) dark unbroken mudstone and sandstone strike 155° and dip west 30°, and lie flat higher up the hill. A mile farther south is the Waipaoa Gorge contact, and six miles still farther south the Mangatu contact described in the extracts from *Bulletin 21*. The contact is shown in fig. 2, where Mr. Macpherson appears at the base of the Tertiary (just to the left of the centre). Similar exposures extend northward from Pipe D Hill, but are not so plain.

The red bed which has been mentioned as $\frac{1}{2}$ in. to 2 in. thick on Pipe D Hill is generally present; in the Mata it is some 4 ft. thick, in other places much thicker. It lies on the top of the Awanui white shale and limestone, and is probably the product of weathering during the erosion interval before the Ihungian was deposited, as inferred by Galloway (Galloway, 1922, pp. 105–6), from the abstract of whose report we quote these passages :—

"Red limestones do not occur in beds of great horizontal extent, like ordinary limestones, but the outcrops only are red. . . . They have long been exposed to weathering . . . or occupy unconformities where they have been subjected to weathering . . . or have been crushed, weathered, and recemented."

"Red limestones are not known to be forming to-day, either in marine or fresh water, even where the conditions postulated for their original

deposition exist. . . . Red limestones are now forming . . . from the weathering and cementation of white chalk and limestone."

"Red limestones were not originally red, but in all cases are due to atmospheric weathering. They always occupy present or past unconformities or crushed zones."

It may be argued that some of the red limestones in the East Cape are due to weathering in crush-zones, and that is undoubtedly so; but the conspicuous red beds above the white shale and limestone were evidently coloured during an interval of erosion. So striking is the contrast that Adams named two adjacent streams in Mangatu Survey District "White Stone Stream" and "Red Stone Stream," and farmers in the district when asked about the coloured beds were able to tell where similar beds occurred.

FIG. 2.—Unconformable contact between Cretaceous and Tertiary beds, Mag Creek, Mangatu N.E.

From Pipe D Hill the contact runs north along the Wairangiora and crosses just below the forks extending north-westward to the bush on Kereruhuahua. In the Mata and Puniatara the contact is marked by rock contrast and conglomerates. Two miles to the north-east the head of the Owhena is in ridges of Awanui white shales, and the head of the Whakoau is basal Ihungia conglomerate with 3 in. coal-seams along the stream. Down-stream the Ihungia beds extend a little north of the stream, and the contact after crossing the stream in several places is well exposed in the Mata River at Whakoau Mouth. From there the boundary passes north-east across the south-east of Hikurangi Survey District, with the characteristic Ihungia conglomerates, with thin 1 in. coal-seams well exposed along the Mata River, and the underlying Ihungia mudstone with Tertiary fossils extending some two miles farther west. In the most northerly Ihungia outcrop in the Mata River the red bed which was described as marking the contact at Pipe D Hill, being there $\frac{1}{2}$ in. to 2 in. thick, is some 2 ft. thick.

From the Mata the boundary runs east between the dark *Leda* mudstone in the Koueiumaraea and Te Matarau and the limestone, white shale, greensandstone, and conglomerate in that stream. It crosses the Inungia and the road at the crushed red and white bands, and reaches into the head of Kean Creek. Thence it passes southward, west of Puketiti trig., to Tokomaru Survey District, east across the Pauariki to Mangahawini, and northward along Tawhiti Creek to the coast at the mouth, as described by McKay (*Rep. Geol. Explor.*, No. 8, p. 141): "It is very remarkable how closely the different formations have their boundaries confined to some creek coinciding in their direction with the strike of the junction; this with others being an example, being for more than a mile from the mouth chalk-marls on the one bank and tertiaries on the other." Adjacent outliers with boundaries marked by dark mudstone above white limestone and shale, with a red band at the contact, occupy the basin of Kean Creek, and the area between Waipiro Creek and Te Puia. In many places in the head of Kean Creek the red bed is seen above the white, showing the top of the Awanuian, from which the Ihungian has recently been eroded.

Another outlier of Ihungia and higher beds a mile wide extends along the coast in Waipiro Survey District. The hills, rising in steep cliffs with table-tops, stand out prominently in contrast with the slumping Awanuian hills; and McKay distinguished and mapped them without difficulty, remarking, "In the morning I followed the main branch of the Akuaku Creek till I found that the material in the watercourse was composed chiefly of secondary rocks. I then returned and followed the next branch to the north, but with only the same result, thus arriving at the conclusion —which I had previously inferred from the outline of the ranges—that the saddle between this creek and Whareponga consisted of marls underlying the harder sandstone beds, which are covered by bush of large size, the older rock having but a very stunted scrub on it" (McKay, 1887, p. 132). McKay was thus able to distinguish (1) the secondary rock with scrub, (2) the *Leda* marls with large bush forming the saddle and underlying (3) the sandstone that gave the hills their characteristic outline; he so mapped the formations, but admitted that the relation of the secondary rocks to the *Leda* marls is obscure: "I followed the greensands (Awanui) down the creek, and found, as I before observed, that they were succeeded—whether conformably or not I cannot say—by the *Leda* marls." The boundary runs close to where McKay drew it, being marked by the rock-change at Akuaku, by vertical pink and white crushed beds in the Whareponga below nearly flat Tertiary beds, by the rock difference farther north. Two still smaller Tertiary outliers occur on the coast between Tuparoa and Reporua, well demarcated by lithology from the pink and white beds underlying. Another outlier between the Reporua and the Waiapu is easily recognized on lithology; and the pink beds capping the underlying white limestone is conspicuous in the Reporua and above the road along the Waiapu north of the Mangaoporo. West of this a narrow Tertiary strip, much broken and fault-bounded, extends north from Rotokautuku across the Poroporo and Maraehara to the Awatere. It can be readily distinguished and the boundary drawn on lithology. One contact in the Maraehara has been discussed, and is shown in fig. 3. More convincing is the one on the Waiapu near Whakarei Mouth. There the Awanui light-blue and white fissile mudstone for some two miles along the north bank strike 160° and dip west 50° below a band of chalky limestone which forms a reef in the stream. Above the limestone is 12 ft. of pug and breccia, 8 ft. of dark mudstone, 12 ft. of crushed green

and red pug, and above this dark bluish-grey fossiliferous Tertiary mudstone disturbed and broken, but not even indurated. It has been moved by the fault, it is true, but away from the break it dips generally 30° north-eastward. The difference in the rocks and their attitude is convincing. A mile north of this, in the Mangataikapua, the base of the Ihungia is marked by thin grit bands with carbonaceous fragments and two bands of dark crystal tuff 6 ft. and 12 ft. thick. Another mile farther north the boundary crosses the Poroporo at the red band above the white and below the dark mudstone. Northward it extends over hidden slopes to the Maraehara contact already described, and then turns east along the red bed well exposed west of the Mangatawhito below the steep, dark Tertiary

FIG. 3.—Cretaceous-Tertiary contact, Maraehara Stream, Mangaoporo N.E.

hill and above the slumping white Awanuian. It crosses the stream near the red bed, and extends irregularly south of east to the coast, cut through by the Waiapu, and evidently eroded back from the fault-line.

The same strip is bounded on the west by faults, rock-difference, slump, and the red bed above the white; and the Ihungia has here, too, bands of tuff near its base. Contacts were examined and the boundary fixed in the Whakatu, Mangaoporo, Whakarei, Te Uapata, Poroporo, Pemberton, Maraehara, at four places in the Tangakaka, and two in the Tauranga-kautuku, so fixing the western boundary. The boundary runs east and north round the Tangakaka, and east and north round the Tokatawhitu-whitu and Mangatakawa, controlled by faults. It runs west north of the Kopuapounamu, and north-east south of the Karakatuwhero, including the dark mudstone of the high country in the Ihungian, and excluding the white shales exposed by erosion in the streams. The boundary passes north-east close to the Karakatuwhero, excluding the volcanic mass of Pukeamaru-Harakeke, and passes north to Iron Point, where the contact

of the basal Ihungian on the volcanic is well exposed. About this contact there has, however, been some difference of opinion. From Iron Point the boundary extends westward above the agglomerate, and below the conglomerate to the Oweka. It was observed in Pah and Haungakaka Creeks below the escarpment that trends away to the south-west, and was observed again along the same escarpment in the Whangaparaoa and Waikura. Along the north of the Wharekahika Valley basalt agglomerate and basalt conglomerate outcrop below the sandstone and mudstone, but no good exposure was seen, and the boundary is drawn to exclude the agglomerate and include the conglomerate in the Ihungian. In the north the igneous rocks of Mangaroa Range and Pukeamaru intervene between the Cretaceous and the Tertiary. The highest Cretaceous rocks are the limestone and chalk-marls, and were deposited free from volcanic material. The contact of the Ihungia series and the volcanic rock in the north has caused some differences of opinion. In 1877 Cox described the solid flows as extending continuously from Cape Runaway to Matakaoa Point, "where they pass by degrees into a coarse angular agglomerate, and continue as such into Hicks Bay"; and of the contact he wrote, "as they are overlaid by the oyster-bed which is the lowest member of the Tawhiti series, as here developed, they must be, at least, of upper Eocene age" (Cox, 1877, pp. 112–13). In 1912 Clarke referred to the contact (*Rep. Geol. Explor.* No. 10, pp. 112–13) in these words: "Unconformable junctions between these strata [claystone and sandstone] and the igneous rocks appear near [Te] Koau Point [=Iron Point], where limestone appears to replace the sandstone." In 1914 Marshall wrote: "On the south side of Hicks Bay the volcanic rocks are interstratified with the limestone of Tertiary age, and they evidently represent the products of volcanic activity in relatively deep water, judging from the nature of the associated limestone and by the absence of oxidized material and of steam-pores in the fragmentary matter. Tuff and scoriaceous material is interstratified with the limestone" (Marshall, 1914, p. 284). The outcrops examined during this work agree with the observations of Cox and Clarke. It is true that on the south side of the bay pebbles of the volcanic rocks are included in the Tertiary limestone, and fine examples may be seen in the new road-cuttings, or, better still, in the waves on the south of Iron Point, by any one who can scale round. There the limestone contains large oysters and well rounded and smoothed pebbles of basalt. Out towards the point the limestone dips south into the sea, and also contains well-rounded basalt pebbles, some of which are being eroded in a peculiar way, producing hollow balls. But the stones are well rounded, and indicate that the basalt was being eroded while the limestone was being deposited, and cannot indicate contemporaneous vulcanicity during limestone deposition. Farther out towards the point the basal Tertiary limestone, with some large angular pieces of basalt, rests on the basalt agglomerate with much tachylyte. The line of separation is not well marked, but it is not to be expected that stones moved out of the agglomerate and redeposited on it will give a sharp, well-marked contact. The tuff bands that occur at the base of or low in the Ihungian have been already mentioned, but they are distinct from and later than the basalt-flows. On the south side of Wharekahika Valley, in the creeks flowing north from the mountain, the solid basalt is overlain by agglomerate above which is limestone with rounded pebbles of basalt; and this sequence extends across the district to the Oweka. There bands of shell rock striking 130° and dipping north 20° are underlain by bluish arenaceous sandstone which does not stand

well and so does not give good outcrops. Along the Oweka, south of the shell rock, no solid rock crops out for the next 30 chains; there, east of the stream, a hard light-blue mudstone, indurated and shattered, crops out. It is unfossiliferous, and similar to the chalk-marls of McKay—that is, to the Awanuian; therefore the 30 chains without outcrop was re-examined. No solid rock crops out, but there are some 10 ft. boulders of coarse conglomerate with subangular 1 ft. boulders of basalt and smaller pieces more rounded like the other stones of the conglomerate, among which are greywacke, some small pieces of pink mudstone, and green chert. The pink pebbles look like pieces from the oxidized erosion surface above the chalk-marls, the green chert are pieces from the chert in the lava, and the large unrounded pieces of basalt are probably from the agglomerate there, and the rounded pebbles show erosion, so there is strong evidence for an erosion interval after the volcanic action. As no solid outcrops could be seen in the Oweka, Strike Creek, which flows from the east behind the shell-rock dip-slope, was examined. The mouth of it is occupied with pug which includes some shell-rock boulders. About 10 chains up, the blue sandy mudstone encloses bands of conglomerate containing well-rounded and polished bouldes of gneissic gabbro, grey gabbro, quartz, greywacke, basalt, granite, pieces of Raukumara sandstone with *Inoceramus*, pieces of white concretions evidently from the chalk-marls, and soft pieces of mudstone and sandstone. The gabbro pebbles are particularly well rounded and polished, and range up to 3 ft. in diameter. The conglomerate is in places bedded; in others it is enclosed in pockets in the mudstones. It extends for about 10 chains along the creek. South-east of it, and dipping 60° evidently under it, is the coarse conglomerate that forms the conspicuous cuesta and fault-scarp, south of Strike Creek. In it there are some well-rounded 1 in. pebbles of red chert, and some large oysters, but most of it is rounded coarse basalt with some subangular pieces up to 2 ft. through. It is interbanded with 2 ft. beds of the mudstone, and underlain by agglomerate and lava; but in this locality the contact between the unbedded angular agglomerate and the bedded, rounded, re-sorted material derived from it, forming the conglomerate, was not noticed.

The physical evidence of unconformity is confirmed by the palaeontology. The white shales and the light mudstones below contain Ammonites; the fine-grained limestone contains fucoids described by McKay as the Amuri fucoid; and Ammonites from Awanui have been identified by Marshall as Senonian forms. The fauna from the conglomerates near the base of the Tertiary has been classified by Mr. Marwick as late Awamoan.

The Cretaceous fine mudstone, greensandstone, white shale, and fine-grained limestone were evidently sediments laid down when the source of the sediment was peneplained to a lowland. This stage seems to have synchronized over the New Zealand area, and so to validate the correlation of the argillaceous (Amuri) limestone beds from Canterbury to Northland as it has been used by McKay and Marshall. Unless diastrophism intervened, terrigenous sediments could not have continued much longer; but this sedimentation from the peneplained land was in the east coast interrupted by volcanic outbursts, during which much fragmental basalt and tachylyte was ejected, and basic lavas and dykes were poured out and intruded. The sediments were folded, elevated above the sea, eroded, again depressed, and covered over first with fine sediments enclosing an Awamoan fauna, and later with coarser clastics. Some of the basalt is much shattered and slickensided, and was evidently poured out before the folding ended.

Earlier Hypotheses rejected.

The evidence of this unconformity is irresistible, and shows that Marshall's conception of New Zealand geology, with the Oamaru series as a simple uninterrupted sedimentary series ranging from Clarentian to Castlecliffian, and Thomson's hypothesis of the Notocene ranging from Clarentian to Castlecliffian as a series of strata deposited during the quiet period between two diastrophic movements, are not tenable.

Geographical Extent of the Unconformity.

That such an unconformity, so strikingly marked, has been ignored suggests that other sections showing the same unconformity have likewise been passed over. On examining the reports we find that McKay has recorded a section showing unconformity in Hawke's Bay (McKay, 1879, pp. 71, 74), where the underbed is white marl with Ammonites resembling the Amuri limestone, and the overbed is the Te Aute limestone. He has described and figured, too, in Wairarapa, unconformity between limestone identified as Amuri limestone and calcareous greensand identified as Hutchinsonian or Mount Brown (McKay, 1879, opp. p. 78). Evidently, then, there is regional unconformity above the fine-grained (Amuri) limestone extending the length of the east coast, and it is thought likely that it extends to the South Island, for there, too, in places, an erosion interval occurs above the Amuri stone, as appears in the photos by Speight (Speight and Wild, 1918, pp. 74, 75). What is more, it is necessitated by the nature of the sediments, for without elevation of the land sedimentation from the peneplaned old land could not have been renewed. Moreover, after the fine-grained (Amuri) limestone was deposited igneous rocks were intruded, poured out, and ejected. They have been recognized during this survey at many places from the North Coast to Waitangi Hill. McKay also recorded crystalline and amygdaloidal lava associated with the (Amuri) limestone on the coast of southern Hawke's Bay (McKay, 1887, p. 190) and in the Wairarapa, where he recorded, "so far as I can put the evidence together it appears that volcanic activity showed itself for the first time during the deposition of these rocks after the Amuri series had been laid down" (McKay, 1884, p. 75). McKay's statements, however, are not definite, and may be interpreted variously. Likewise in North Auckland Ferrar and Cropp reported that "During the Cretaceous depression claystones and impure limestones accumulated on the sea-floor in the present North Auckland area. Next in early Tertiary times the folding of the first-described cycle gave place to faulting accompanied by elevation, and by the eruption of igneous rocks of intermediate composition. In places the soft Cretaceous strata were wholly removed by the denudation consequent on the uplift. After peneplanation the land once more began to sink" (Ferrar and Cropp, 1921, p. 7). Similarly Thomson has recorded tuff in the Herring River and lava in the Ure Valley between the Amuri stone and the Weka Pass stone (Thomson, 1919, pp. 324, 327).

Examination of the unconformity below the Tertiary of the east coast and comparison with other reports lead to the conclusion that deposition continued through the late Cretaceous over the New Zealand area till the land was peneplaned, when green sandstone and fine-grained (Amuri) limestone were deposited, evidently contemporaneously, from north Canterbury to north Auckland. Then the sediments were folded and elevated, and during the folding igneous rocks were intruded and extruded. This land was then eroded, and in the Tertiary depressed and covered with sediments containing Tertiary fossils.

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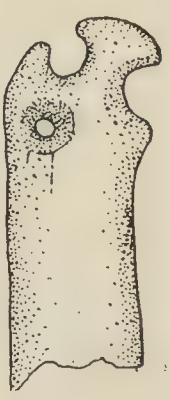
TANGIWAI EAR-DROP COLLECTED BY CAPTAIN COOK.

By W. W. Thorpe.

Amongst the most valued objects in the Cook relics now on view in the Australian Museum is a bowenite (tangiwai) ear-drop. It is 13½ in. long, and weighs 5¾ oz. The apex is bevelled off on one edge, resembling the point of a sword, and the stone used is of a light translucent green. A two-ply knotted string traverses the perforation at the proximal end, to which is attached, by a simple knot, a hank of red-brown flax.

It formed part of the John Mackrell Collection, displayed in the New South Wales Court of the Colonial and Indian Exhibition, held in London during the year 1886. In the printed catalogue it is described as a "New Zealand jade ear-ornament. One of the most beautiful specimens known. Worn by a New Zealand chief through his ear as an ornament, and presented by him to Captain Cook."



On account of this latter statement the present writer thought that a search through the *Voyages* might reveal some record of the transaction, but the best evidence that can be offered is that to be found in the *Second Voyage* (vol. 1, p. 75, 3rd ed., 1779). Under "Dusky Bay, April 7th, 1773," the following is recorded: "When we took leave, the chief presented me with a piece of cloth or garment of their own manufacture, and some other trifles." Whether the ear-drop was numbered amongst the "trifles" no one can now say. Captain Cook mentioned greenstone several times, always referring to it as "talc" or "green talc"; and in the Hawksworth edition (vol. 3, plate 13, opposite p. 453) the head of a New-Zealander is depicted with such a pendant attached to the right ear.

The line drawing shows the detail of the perforated end, which is more or less obscured by the loop and fibre.

KAREWA : AN ISLAND SANCTUARY.

By BERNARD SLADDEN.

THE Islet of Karewa, situated in the Bay of Plenty, lies to the north-west of Mount Maunganui, at the southern entrance to Tauranga Harbour, and is distant therefrom about seven miles.

In the Maori tongue the name Karewa signifies to "uplift," and it is here associated with a common phenomenon of nature, in which, from a distance the islet appears to be suspended between sky and water. This illusion may often be observed when atmospheric conditions are such as to produce the mirage-like effect.

In extent Karewa has a bare 9 acres, and were it not for the fact that this spot was one of the earliest-known habitats of the reptilian tuatara

Karewa Island.

(*Sphenodon punctatus*), and the nesting-place of many birds of the petrel family, so insignificant an islet would scarcely have claimed attention among the scores of other pinnacles and rocks of a like nature which extend in a chain along the north-eastern seaboard.

As long ago as 1842 the naturalist Ernest Dieffenbach records the fact that he had obtained possession of a tuatara that had been captured on Karewa, in which connection he writes: "Off the entrance to Tauranga Harbour is a small island, which I attempted to reach in a boat, but was obliged to put back on account of the heavy swell. . . . It is a mere rock, but possesses some interest as being the only spot I know of in New Zealand where the new species of reptiles exist which were brought over by me to England."

Viewed from eastward, Karewa presents a decidedly rugged appearance, the steep faces arising abruptly from deep water to a height of 300 ft., and

terminating in an accumulation of rocks which form the highest point of the islet. Toward the south and west, however, the contour is less broken, and the ground falls away in a gentle declivity to the water's edge, the slopes being clothed with verdure, conspicuous amongst which is the glistening foliage of the taupata scrub (*Coprosma Baueri*). On these lower slopes, in the loose soil, the petrels have their burrows, and share them in a spirit of friendly toleration with their strange companions, the reptiles of peculiar structure and ancient lineage.

FAUNA.

Although the tuataras had been removed from Karewa in large numbers before protection was accorded them, the reptile may still be considered plentiful on the islet. It is to be seen in its characteristic posture, extended motionless on a rock or prostrate limb; or, with head and shoulders protruding from a burrow, it will permit the near approach of the intruder on

Tuatara (*Sphenodon punctatus*) on prostrate limb of *Coprosma*.

its domain before disappearing silently into the recesses of the burrow. Other evidences of the existence of the tuataras may be observed in the tracks left on the ground by the trailing bodies, by the presence of deposits showing the undigested remains of black-winged beetles, and by fragments of the parchment-like epidermis which is periodically shed by this reptile and is often to be found in the vicinity of the burrows.

When taken from below ground and subjected to handling the tuatara appears dull and stupid, and incapable of anything but sluggish movements. If, however, it is disturbed when outside the burrow it can display a considerable amount of activity in its efforts to find a place of refuge.

Besides the tuatara, Karewa possesses in small numbers another reptile, a soft-skinned lizard of the family of geckos.

AVIFAUNA.

By far the most plentiful amongst the bird community of Karewa is the flesh-footed shearwater (*Hemipuffinus carneipes*), or taonui of the Maoris.

This petrel congregates in vast numbers for nesting purposes early in the spring, but the season is well advanced before the egg is laid and incubation commences, for no young birds are to be found before the first week in January. When alighting at the nesting-ground the petrels drop through a canopy of interlacing *Coprosma* branches, and the passage of the birds through the tangle of twig and branch occasionally results in an individual being caught as in a trap, in which predicament a miserable death awaits the captive.

It seems unnatural that a bird so peculiarly helpless in situations such as this should have to force its way through a barrier of scrub in order to reach its nest, and it is a reasonable inference that generations ago, when the spot was first selected as a breeding-ground, Karewa may have been devoid of anything in the nature of a plant covering. As the centuries passed, the weathering of the soft rhyolites and the accumulation of guano

Breeding-ground of the petrels, showing interlacing stems of *Coprosma* scrub, and surface of ground undermined with burrows.

and decaying fish and animal matter would provide a congenial nursery for the plant formation as it now exists.

In point of numbers the diving-petrel (*Pelicanoides urinatrix*) comes next to the taonui as a nesting species. About July it takes possession of the shallow burrow, and the single egg is laid and the young bird hatched before the taonui has completed its arrangements preliminary to settling down to the serious duties of motherhood.

Sir Walter Buller, in his book on the New Zealand birds, mentions Karewa as the breeding-ground of no less than four additional species of petrels—viz., Cook's petrel, Forster's shearwater, sombre shearwater, grey-faced petrel. Of these birds, Cook's petrel (*Cookilaria Cookii*) is only an occasional visitor in Bay of Plenty waters, and it may be concluded that it does not breed on Karewa at the present day.

Neither can Karewa claim Forster's shearwater (*Puffinus gavia*) as a nesting species. This bird is gregarious, and resorts to Motunau and Whale Island, off the Bay of Plenty, for breeding purposes. With reference to

the sombre shearwater (*Neonectris griseus*), which is the "mutton-bird" of the south, it would appear that there has been confusion between this and the flesh-footed shearwater, for, as far as can be judged, the birds which congregate on Karewa, arriving at dusk and departing again at daybreak, belong only to the latter species. Among many specimens examined on the islet itself there were no examples of the sombre shearwater.

The grey-faced petrel (*Pterodroma macroptera*), which is nocturnal in its habits, breeds in small communities on several of the adjacent islands, and in all probability a close search would reveal its burrow on Karewa also.

Besides the petrels, Karewa provides a breeding-place for two other species of sea-birds, the blue heron (*Demiegretta matook*) and the blue penguin (*Eudyptula minor*), both of which are plentiful.

Apart from the birds of the sea, Karewa has but few representative species. The white-eye (*Zosterops lateralis*) is present, and the alien blackbird, also the starling, which latter bird arrives in flocks from the mainland at dusk for its nightly sojourn on the islet, and departs again with the advent of daylight.

An occasional harrier (*Circus approximans*) may be seen hovering over the islet, and evidence of its predatory habits is found in the mangled remains of parent birds and young of the diving-petrel, whose shallow burrows afford scanty protection against the raider of the air.

FLORA.

On account of its limited area, Karewa does not possess a wide range in the number and variety of its plant species, but at the same time there are several among its twenty or more kinds whose distribution has become remarkably restricted, and there is a possibility that these plants may disappear entirely from our flora unless protected from the influences that have brought about their extirpation in localities where they previously existed. It might be expected that the vegetation of the small islands off the coast would be identical with that of the coastal shrubberies of the adjoining mainland, but there are certain plants which favour the islets that are the habitat of the burrowing-petrels, and the presence of these plants, together with the generally luxuriant nature of the growth, gives distinctive features to the vegetation in those situations of which Karewa provides a typical example.

Commencing at the water's edge, there are found growing in close association the two common fleshy-leaved maritime plants *Mesembryanthemum australe* and *Salicornis australis*. These cover large areas on the rocks and cliffs, which are dotted with the pink disc-shaped flowers of the former plant.

In places less exposed to wind and spray, where a stratum of soil covers the rock, there grows a member of the cress family, *Lepidium oleraceum*, the "scurvy-grass" of Captain Cook. It is a notable fact that this plant has gone altogether from many localities where in earlier days it had been a prominent member of the coastal plant communities.

The plant which is dominant and chiefly gives character to these island shrubberies is *Coprosma Baueri*, commonly known as the taupata. On Karewa it grows in places to the exclusion of all else, its distorted stems arising to a height of 10 ft. or 12 ft., and, branching out, form a canopy of their glistening foliage.

Associated with the *Coprosma* where the thicket is less dense is the shrubby *Hymenanthera novae-zelandiae*. Here it flowers and fruits

profusely, and the berries, which lie closely appressed along its branches, form, with the *Coprosma* berries, the principal diet of the diminutive white-eye (*Zosterops lateralis*).

A bushy tree of handsome appearance is *Pseudopanax Lessonii*, conspicuous on account of its large digitate leaves of a rich green colour and leathery texture. The tree is not uncommon in the coastal forests of the north, and is plentiful on Karewa.

Towards the western extremity of the islet, where the soil lies deep and rich, is a grove of karaka (*Corynocarpus laevigata*); and this tree provides the only example of a true arborescent form among the more or less shrubby growths of the predominating species.

To this latter class belong three additional members of this plant community, to which a more than ordinary amount of interest attaches. In *Paratrophis Banksii* there is an example of a large-leaf form of the turepo, or "milkwood" of the bushman. This tree is notable on account of its comparative rarity, and, as in the case of its near relative, the male flowers are produced in the form of catkins, a rather unusual style of infloresence in the New Zealand flora.

Growing in close proximity to the previously named tree is *Sideroxylon costatum*, known to the Bay of Plenty Natives as "orewa," but given the less euphonious name of "tawaapu" by writers on the New Zealand flora. This species grows as a small tree or shrub, is nowhere very plentiful, but exists on certain islands and at several points on the mainland northward from Cuvier Island and Cape Colville. Near Tolaga, some two hundred miles to the south-east, there is a single specimen (a tree of historic interest), and within the wide intervening stretch from East Cape to Colville, including coast-line and islands, the only recorded location of *S. costatum* is on Karewa, where it is not a scarce plant. The third member of the group previously referred to is *Pisonia Brunoniana*, the parapara, or "bird-catcher" of the settlers. This tree has a somewhat similar distribution to *S. costatum*, and its most southern location is in the vicinity of East Cape. Curiously enough, also, Karewa has the only specimen so far recorded between that point and Cuvier Island to the north-west. As is well known, the seed-pods of *Pisonia* exude a sticky substance, which it is stated will ensnare the smaller birds that come in contact with the gluey mass—hence the name "bird-catcher plant."

In the order Filices, Karewa has three species, representing two genera —the common fern, *Polypodium serpens*, and two spleenworts, *Asplenium flaccidum* and *A. lucidum*. These two latter ferns provide excellent examples of the effect of environment in producing variations of form from the recognized types.

Asplenium flaccidum grows here, on the bare rock, as a tufted fern with a crown of many finely divided fronds, and few would recognize in it a plant of the mainland forest bearing the same name and usually growing epiphytic from the trunk of a tree, its pendulous fronds often several feet in length and of strap-like form and texture.

Asplenium lucidum grows on Karewa as a purely terrestrial plant, and it occupies large patches on the otherwise naked ground, trampled bare by the passage of the petrels to and from their burrows. This fern attains considerable luxuriance of growth in the over-rich soil, and has a specially stout and stiff midrib and an abnormally developed fleshy rhizome, capable of conserving sufficient moisture to sustain the plant during the rainless periods which prevail in such localities as this.

On the rocky knoll near the middle of the islet the rengarenga, or rock-lily (*Arthropodium cirratum*), grows in profusion, and with it a few immature specimens of another of the same order, the well-known "cabbage-tree" (*Cordyline australis*).

In the shelter of some of the more umbrageous trees a few attenuated saplings of the ngaio (*Myoporum laetum*) exist, having grown weak and drawn in an effort to pierce the stratum of leaves above, and gain a share of the sunshine and salt breezes essential to their better development.

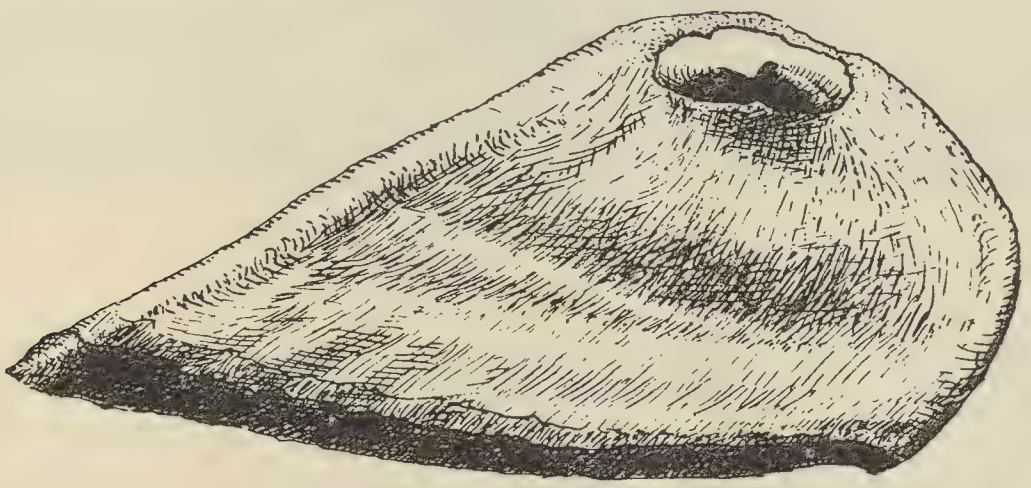
Besides the plants already referred to, Karewa has the following: The succulent *Piperomia Endlicheri;* a creeping-plant, *Chenopodium triandrum;* the scrambling *Muehlenbeckia;* a common seaside plant, *Senecio lautus;* and the cosmopolitan nightshade, *Solanum nigrum.* There are also three annual grasses (not identified), and an alien plant, *Phytolacca octandra*, the "inkweed" of the settlers.

In 1917 Karewa was proclaimed a sanctuary, with a view to the protection of its bird-life; and in no less a degree is its flora worthy of preservation, for it is only in such places as this, free from the destructive influences of grazing-animals and the encroachment of introduced plants, that we can hope to retain in its virgin state an interesting section of original plant-life.

ZOOLOGICAL NOTES.

Strap-toothed Whale stranded at Kaitawa Point, Entrance to Porirua Harbour, by W. R. B. Oliver, F.L.S., F.Z.S.

In January, 1924, Professor Sommerville was good enough to inform me of the presence of a small whale on the coast opposite Plimmerton. As the specimen was described as having a distinct beak, I took the first opportunity of examining it, and found it to be a young female of the strap-toothed whale (*Mesoplodon layardi*), about 16 ft. in length. This



Left tooth of strap-toothed whale.

species is a member of the family Ziphiidae, specimens of which are so rarely cast ashore that their occurrence is always worthy of record. In the adult the teeth take the form of wide bands springing from the lower jaw and arching over the upper so as to effectively prevent the animal from opening its mouth to any extent. In the present specimen each tooth is triangular, with the denticle well developed and projecting outwards at right angles to the basal portion, which is entirely enclosed

in the alveolus. Although in the adult the teeth are convex on the outer surface, in very young specimens the outward-projecting denticle gives the appearance of the teeth having the concave surface outwards. The general appearance of the strap-toothed whale has already been described in this *Journal* (vol. 5, p. 136).

With the assistance of Messrs. Hamilton and Phillipps, of the Dominion Museum staff, the bulk of the flesh was cut off the whale and the bones buried in sand. They were then left for several months, when it was found that practically all the flesh easily came away, and the skeleton was transferred to the Dominion Museum.

This is the ninth specimen of this species that has been recorded within the New Zealand area.

The accompanying drawing was kindly made by Miss E. Richardson.

Stranded Blackfish at Marsden Point, by W. R. B. Oliver, F.L.S., F.Z.S.

For the opportunity to place on record the stranding of a school of blackfish near Whangarei I am indebted to Mr. W. M. Fraser, Whangarei Harbour Engineer; while the Art Studios, Whangarei, have kindly given me permission to publish the accompanying photograph.

Stranded blackfish at Marsden Point.

The blackfish (*Globicephalus melaena*) is usually found in schools, often of considerable size. The animals apparently trust to one or more leaders, and when these inadvertently get into shallow water the whole school follows, with disastrous results. So strong is the gregarious instinct that when some fishermen drove one of the Marsden Point school into deep water it turned back and ran ashore, stranding itself again alongside its mates.

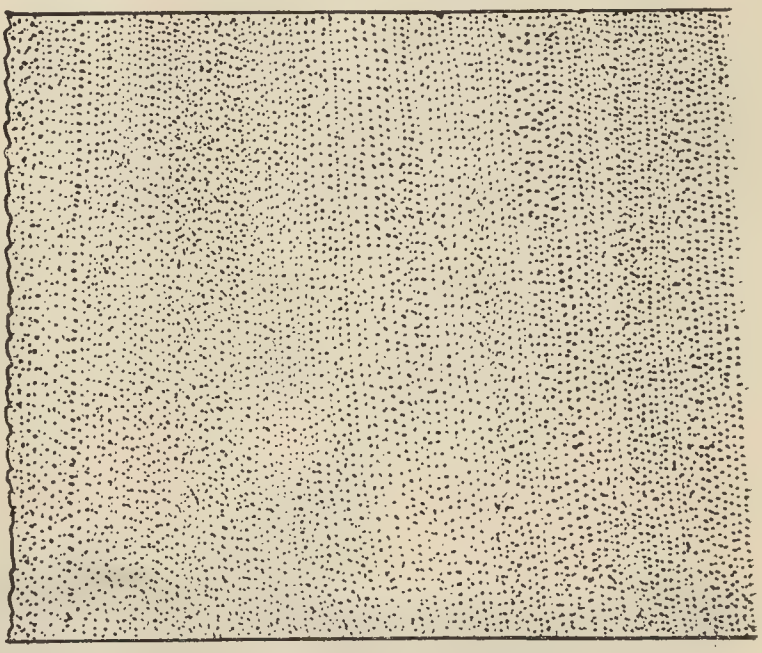
The school, seventy in number, came ashore on a sandy beach at Marsden Point, just inside Whangarei Harbour, at 10.30 p.m. on the 4th August, 1923. The adults were all dead within four days of stranding, but the calves had to be killed by the settlers (who wanted the blubber) after they had lain on the beach for six days. There were twenty-three males and forty-seven females, two or three of the latter being in milk.

The largest specimen measured 20 ft. in length and 11 ft. 4 in. in girth, and there were a number of calves 6 ft. to 7 ft. in length. The colour was glossy black, with a large white patch just behind the dorsal fin. There are also patches of white on the under-surface of the head and body.

Note on the Spawning of *Doris wellingtonensis* Abraham, by Maxwell Young, F.C.S.

The gasteropod *Doris wellingtonensis* Abraham is not very common in Otago Harbour, and we have had only two specimens in the tanks at the hatchery within recent years. One of these was kept in a glass observation-tank, where it spawned, and about two months later died.

The spawn was laid during the night of the 9th October, 1923, and a little the following day. It was orange-yellow in colour, ribbon-like, and curled round the weed to which it was attached. The eggs were arranged in rows of approximately one hundred to each row. In size they were about as large as a small pin-head. The "ribbon" of spawn was 1 in. wide and 11 in. long, so the total number of eggs must have run into many thousands. All attempts to hatch the eggs failed.



Spawn of *Doris wellingtonensis*.

I have also a record of this gasteropod spawning at Waitangi, Chatham Islands, in February of this year. Probably the spawning season extends over the whole of the warmer months, and is not limited to a short period, as in some marine animals, where all the individuals spawn within a few weeks of one another.

It may be of interest to note that the jelly is clear, the yellow colour being supplied by the closely packed eggs. The illustration gives a diagrammatic representation of the spawn, and shows the arrangement of the eggs in the gelatinous investing mass of the spawn.

Occurrence of the Echinoderm *Goniocidaris umbraculum* Hutton, by Maxwell Young, F.C.S.

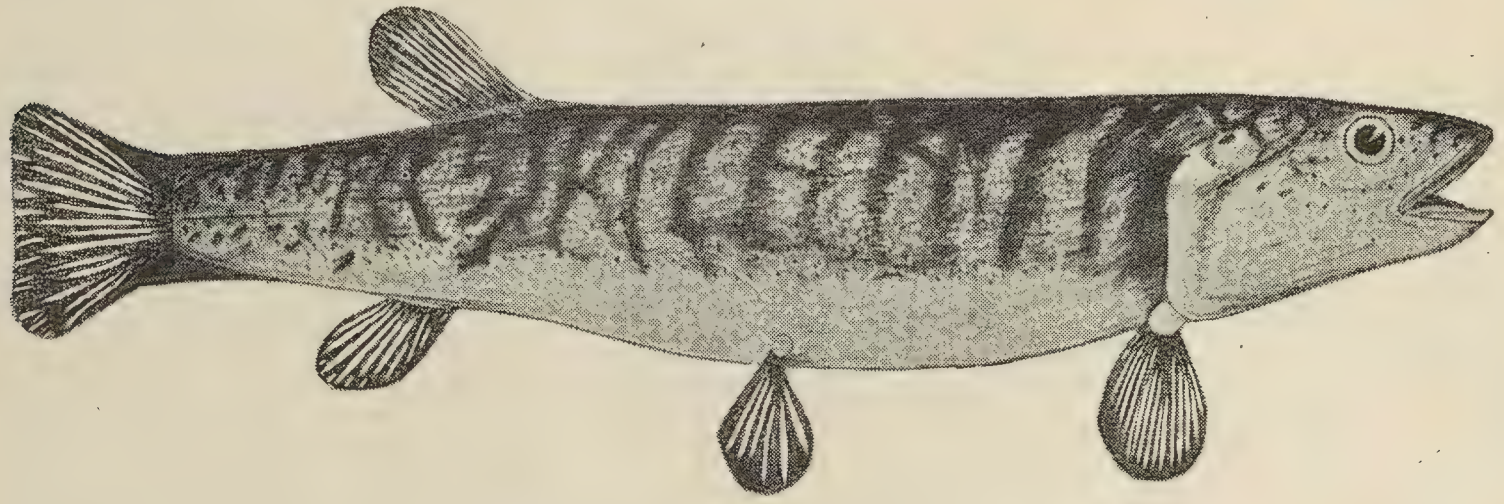
A large number of specimens of this interesting little echinoderm were picked up by the dredge in 60 fathoms of water nine miles east-north-east off Otago Heads. This species has generally been considered rather rare, but it is evidently more plentiful than has been supposed, as two subsequent dredgings at approximately the same depth but in different localities have yielded a fair number of specimens. The individuals varied greatly in size, from tiny specimens which could be concealed by a threepenny-piece to adults which were nearly all of a uniform size with a body-diameter of 2 cm. and a diameter between the tips of opposed spines of 3·25 cm. The most striking feature of these echinoderms is to

be noted in the spines. Those on top are of the usual shape, but the ones on the under-side are dilated at the tip so as to form a concave terminal disc. The species has previously been recorded from Foveaux Strait and Stewart Island. An interesting account of the range of the genus is to found in the "Challenger" Reports, although this particular species was not obtained. This report also shows that the bathymetric range of the genus is from 0–1975 fathoms, as follows:—

Species.	Bathymetric Range.
G. canaliculata A. Ag.	Shore to 1975 fathoms.
G. florigera A. Ag.	100–129 fathoms.
G. geranioides Agass.	Shore.
G. tubaria Lütk	Shore to 40 fathoms.

The Koaro: New Zealand's Subterranean Fish, by W. J. Phillipps, F.L.S., F.R.G.S.

Galaxias huttoni, the koaro of the Maoris, is found only in Lakes Rotoaira and Rotopounamu, at the base of Mount Tongariro. I have had the opportunity of paying a number of visits to these lakes and making interesting notes on the habits and life-history of this fish. Around each of the lakes above named are numerous hot springs. Most of these springs are of considerable volume, and run from subterranean channels into the lake. The Maoris assert that the koaro hibernates underground in these springs during winter, and is seldom seen from March to October each year.



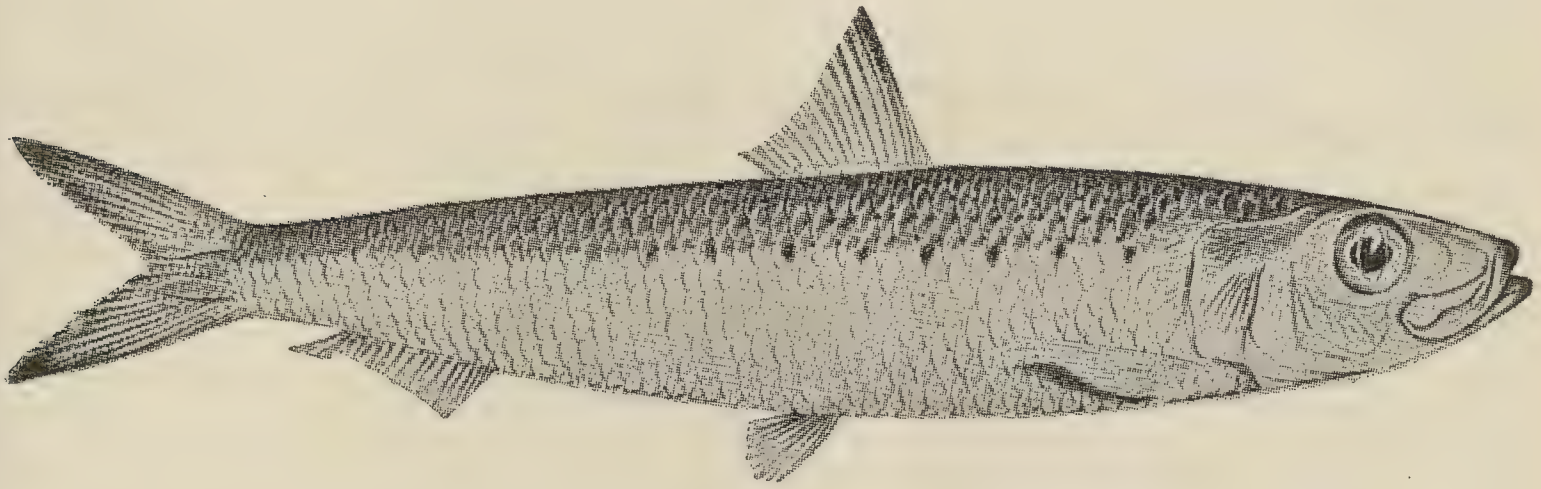
The koaro (*Galaxias huttoni*),

In November of each year Tokaanu Maoris journey to Lake Rotoaira, where they remain for a few months and secure enormous numbers of this fish. In the summer of 1920 I had the opportunity of visiting such an encampment and observing the ingenious manner in which koaro were caught. A large spring is selected, and operations commence at 2.30 in the morning, when a fishing-party armed with a hinaki, or funnel-shaped basket net, visit the spring and place the hinaki with the mouth pointed towards the lake to block the entrance of fish from the lake to the underground channel. The fishing-party then return to bed. About 6 a.m. the hinakis are raised, and found to be crammed with koaro from 2 in. to 6 in. in length. These are emptied on raised platforms at the edge of the lake and spread out to dry in the sun. Constant turning is necessary, and when properly dry the fish are salted and packed in barrels for winter consumption.

In regard to the Maori assertion that this species hibernates during winter, it is possible that such is the case. My own observations are as follows: In September it was possible to secure only a few larval specimens under overhanging banks. Adults could be secured in the same place in small numbers a month later. Large adults, 6 in. long, were easily secured after the manner of the Maoris in the summer of 1920. Larval specimens appeared to have grown considerably. Until the time taken for eggs of this species to incubate is determined it is impossible to state the date of spawning. Demersal ova possibly ready for extrusion were found in females examined during January and March. Certain it is that with the first emergence of the koaro into the lake during the spring months large numbers of larval specimens are common.

Sardines or Pilchards in Wellington Harbour, by W. J. Phillipps, F.L.S., F.R.G.S.

During the month of July, 1924, Wellington Harbour was visited by an enormous shoal of pilchards, or sardines *(Sardinia neopilchardus)*. As has already been stated by Dr. J. Allan Thomson in the first volume of this *Journal*, our New Zealand sardine is closely related to the famous European sardine, *Sardinia pilchardus*, which is taken in tons off the coasts of France and Spain. Recognizing the species, sailors on boats at the wharf quickly adopted a method of taking it akin to that used in Europe. Mashed potatoes, bread-crumbs, and like minute foods were thrown into the water, and almost immediately hundreds of pilchards



The southern pilchard (*Sardinia neopilchardus*). (After McCulloch and Kinghorn.)

would crowd to the spot. A basket-shaped net, open at the top, and made from wire netting, had previously been lowered into the water. This was now raised suddenly and numbers of pilchards secured. French fishermen generally set a floating bait, such as the spawn of large fishes, and take the sardine in fine-mesh nets in the open sea.

On entering the harbour the sardines seemd to divide up into several shoals, as could be determined by the movements of sea-birds. Large numbers of gannets were to be seen diving with their accustomed rapidity, and these, together with several species of shag, were for a few days at the end of July the most common birds in the harbour. Many local amateur fishermen secured considerable numbers of the species after the manner described above. This fish is identical with the well-known "Picton herring," which is sold in a smoked condition every winter in Wellington.

Occurrence of the Australian Giant Wood-boring Moth in New Zealand, by Amy Castle.

In February, 1923, Mr. J. Day, officer of the s.s. "Omana," brought to the Dominion Museum, Wellington, two specimens of a large moth. Both were females in a very feeble condition, and died a few days later without discharging any eggs. The specimens were sent to the Australian Museum, Sydney, for identification.

Zeuzera boisduvalli is the giant of the family Zeuzeridae. The female specimens, grey in colour, measure 9 in. in wing-expansion, have large heavy bodies, and are capable of discharging thousands of eggs. An enormous number of these are apparently eaten by ants. The eggs are deposited on the tree-trunk of the *Eucalyptus* trees, and when hatched eat their way into the interior, forming extensive galleries and causing serious damage, as may readily be judged by their size.

A third specimen, male, measuring 6 in., was presented to the Dominion Museum by Mr. R. F. Keayes, of Wellington, who found it alive between the waterfront and the Hotel Cecil (January, 1924).

These moths do not possess a proboscis, and apparently take no food in the adult stage. Their wings become very brittle soon after emergence, and the moths seem quite incapable of flight.

It would be a serious matter should these insects establish themselves in New Zealand.

Occurrence of *Precis villida* at Nelson, by R. E. Grimmett, M.Sc.

While visiting Nelson for a few days during April, 1924, I was surprised to see a number of *Precis villida,* mostly appearing in almost perfect condition. My attention was drawn to the first one by my father, Mr. T. R. J. Grimmett, of Ngatitama Street, where it was settled near some flowers in his garden. No net being handy, an attempt was made to catch it with a hat; but, though it returned repeatedly to the same spot, it proved too elusive.

On the 20th (two days later) a pair were noticed frequenting a patch of gravel on the roadside in the same locality, and I was able to secure these with a net. The male was in the better condition.

A few days later another was seen, and nearly captured, but escaped into a clump of grass, where it could not be found. Others probably of the same species were noticed on the wing, but could not be identified with certainty.

Mr. Philpott, Entomologist of the Cawthron Institute, informs me that he noticed some about in the summer of 1923, but did not succeed in capturing any.

All the butterfles seen were in the warm and sheltered locality at the base of the Grampian Hills. It would be interesting to know if the visitation were at all general in the Nelson District or elsewhere. Owing to lack of opportunity I was unable to investigate this.

So far as can be ascertained, this is the first record of capture of this butterfly in New Zealand (it occurs also in Australia) since a single one was caught by Mr. H. Hamilton on Mount Greenland in March, 1910. Previous to this it had not been seen since 1898. Mr. Hudson (*New Zealand Moths and Butterflies*) reports it as common about Wellington in 1886.

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By A. M. WRIGHT, A.I.C., F.C.S., Chief Chemist New Zealand Refrigerating Company (Limited).

THE canning of food is important because it provides a method of equalizing the food-supply from season to season or from year to year, and thereby helps to stabilize prices; it makes it possible to transport foods more easily for long distances, so that the surplus products of one locality may be used to supply other localities where there is a shortage; it provides a more healthful and varied diet; and it prevents waste of perishable foods by providing a method by which they may be kept for future use.

The preservation of foods by heat and their enclosure in hermetically sealed containers, like the manufacture of margarine, had its origin as a war product. Among the military measures enacted by the French Government towards the end of the eighteenth century was the offering of a bounty for an improved method of preserving foods. The object was to secure better quality, and to reduce the loss and spoilage in foods used in military and naval stores. Nicholas Appert, an expert confectioner, brewer, distiller, and chef, was among those who began experimenting; he worked for ten years before he attained in 1804 his first success, which consisted in heating the product and then hermetically sealing the container. He continued his efforts, using many different substances, and so perfected the art that in 1810 he published the results. He was awarded the prize, and almost universally honoured as the discoverer of the art of canning.

With certain reservations, which will be stated later, canning may be defined as the art of preserving a food through sterilization by heat, and maintaining it in that condition in an hermetically sealed container. In its highest development it is an attempt to maintain the food in as nearly

* Paper read to the New Zealand Sanitary Inspectors' Association (Christchurch Branch).

the natural condition as possible, or in the condition in which it is usually consumed (1, 2).

Recent investigations on the bacteriology of canned meat and fish show that these products are at best only partly sterilized, and for the most part contain certain types of living bacteria, but unless air gains access to the tins through minute holes they are unable to develop in such a way as to cause decomposition of the food (3, 7).

In the past the cause of canned food going bad has been attributed to bacteria from the outside air finding their way into the can through minute leaks due to rust or to faulty tinplate; but a long series of experiments has shown that far more importance is to be attached to the supply of oxygen to the bacteria already present in the can, and that the food is sound owing to the absence of oxygen rather than to its being sterile. At the same time, an efficient sterilization process, which is capable of destroying those species of bacteria which decompose food products in the absence of air and sometimes form deadly toxins, is not only necessary, but is the only safeguard against food poisoning, especially that associated with *Bacillus botulinus*.

During the early days of the canning industry the methods employed were held as secrets and carefully guarded, even from employees of the plant. As the industry developed it gradually became evident that canners were all guarding substantially the same information, so that the policy of secrecy in technical operations was of little if any value.

It was perhaps natural, during the unscientific period of development, that along with the good and sound practices there was much that was bad. Fads and superstitions, notions and prejudices, uncertainties and bad practices grew up and took rank alongside a very excellent and logical development; but they cost the industry many thousands of pounds, and by the application of scientific principles could have been remedied much earlier than they were. It was at that time a rule-of-thumb process developed by so-called practical men, who are often very far from practical in the real sense of the word. The curing department was a secret place, presided over by an "expert," so called, who kept his formulae in a little book in his inside coat-pocket, and his secret ingredients in a cupboard under lock and key; his hydrometer, thermometers, and steam-gauges had sliding scales in order to further protect the mysteries. No alchemist of the Middle Ages was more equivocal and obscure than the head of the curing-cellar and process-room (4).

Much of the mystery disappeared with a knowledge of the reasons underlying food-spoilage. Everywhere—in the air, soil, and water, and on everything we use—there exist tiny plants or organisms known as bacteria, yeasts, and moulds. When these organisms are allowed to grow in or on food they cause spoilage. If they can be destroyed and otherwise prevented from attacking the food it will keep indefinitely.

Some of the most deep-seated and pertinacious obsessions have been associated with the chilling and freezing of meat. One of these has to do with a certain philosophical abstraction which is known as "animal heat." This "animal heat," to certain minds, was something different and apart from any other sort of heat, and had to be removed by special means before one could proceed with direct chilling or freezing. If meat were placed in a chill room, or into pickle, or into a freezer before the "animal heat" was removed the meat would spoil. It has now been shown that these ideas are fallacious, and that the so-called "shelling over," due to

superficial freezing when meat is run into a freezer, is not a detriment, but is a benefit so far as preservation and keeping-qualities are concerned. All but a few of the old-time so-called practical men now realize that the sooner the product is chilled or frozen the better its keeping-qualities will be.

Questions sometimes arise regarding the wholesomeness of foods which have been consumed. Any sudden attack of illness involving abdominal distress is likely to be construed by consumers, and sometimes by physicians, as evidence of food poisoning, and some articles of food recently consumed, and which the patient is not accustomed to eating, are sometimes designated as the probable cause of the illness.

A study of food poisoning is one that pertains peculiarly to public health, and it involves all classes of foods. There is no type of food poisoning that is peculiar to canned foods.

During the last generation our ideas of the character and cause of food poisoning have undergone a fundamental change. A generation ago a type of illness characterized by purging, vomiting, and great intestinal pain was known as " ptomaine poisoning," and was believed to be caused by chemical products due to the splitting of the proteins by bacteria of unknown origin. Something more than twenty years ago it was shown in Europe that illness of this type was caused by a group of micro-organisms known as the Gaertner bacteria, of which the paratyphoid bacterium is a type.

It is known, of course, that poisonous substances are produced in the later stages of putrefaction, and usually these so-called " ptomaines " do not begin to appear until putrefaction has been in progress for a week, but generally several weeks must elapse, and long after the most obtrusive signs of putrefaction are apparent. They represent late protein-degradation products. Under ordinary commercial conditions no one would be stupid enough to vend such food, no one would be rash enough to eat it. In other words, ptomaines are only produced when the food is far too nasty to eat (5).

In recent years, Rosenaw and his associates have concluded that the term " ptomaine " is entirely a misnomer, and have been unable to find any evidence of the existence of decomposition products produced in food by bacteria which are poisonous when taken by the mouth. It is now recognized, therefore, that the so-called ptomaine poisoning is caused entirely by infection, and can be prevented by the ordinary precautions demanded for the prevention of infection. Bacteria of this class are not spore-formers, and hence do not survive the heat of processing canned foods.

During the past few years the *Bacillus botulinus*, long known in continental Europe, has caused a number of cases of illness and death. This is the only spore-bearing organism which produces substances that are poisonous when taken by the mouth. The toxins of *Bacillus botulinus* are destroyed by efficient cooking, so that in the ordinary course of manufacture during commercial canning there is but little danger from the toxins already formed in the foods.

The maximum resistance to moist heat of the spores of *Bacillus botulinus* artifically produced under the best laboratory conditions is found to be as follows: 4 minutes at 248° F., 10 minutes at 239° F., 33 minutes at 230° F., 100 minutes at 221° F., 330 minutes at 212° F. It will be seen from this that the high proportion of cases of botulism attributed to home-canned products as compared with those packed commercially is due to the methods and temperature of sterilization (6).

It sometimes happens that canned foods, or the cans containing them develop some type of discoloration, either during processing or during

subsequent storage. When foods of high protein content are heated a trace of hydrogen sulphide is liberated, which gives rise to several forms of discoloration in canned foods (8).

With some varieties of canned foods, such as beans, the hydrogen sulphide combines with the tin and forms a more or less dark discoloration over the entire inner surface of the can, except that bordering on the space at the top of the can. With other products, such as meats, the hydrogen sulphide liberated from the protein by the heat of processing passes into the space at the top of the can and combines with the iron of the top, forming black pulverulent patches, which may either adhere to the plate or be rubbed off into the contents of the can ; usually the discoloration forms but a film of metallic sulphide, which adheres to the surface of the inner top of the can. This dark substance is not at all injurious to health, and no objection can be made to it except from the standpoint of the appearance which it gives the container and product. Its appearance, however, is objectionable, and the industry does everything possible to reduce and if possible to prevent it.

A large amount of study has been given to a consideration of the desiderata in tinplate intended for canning purposes in order to determine the character of the plates best adapted to can-making. The question is much more complex than might be expected, as the investigations have shown that by increasing the weight of tin coating there is no increase in the amount of tin dissolved by certain foods, as was formerly believed by many to be the case. On the other hand, increasing the weight of coating does not materially reduce the number of perforations. Again, it has been found that the use of heavy tin coating does not prevent the formation of discoloration (8).

Spoilage in canned foods is usually, perhaps always, due to one of two causes—defective sealing of the can, or understerilization ; to these must be added the spoilage due to perforation of the container.

Spoilage in canned foods is usually made evident by the swelling of the can ; but when it is due to acid-forming organisms, which do not generate gas, the ends of the can remain flat, and the product is known technically as a "flat sour." Bulged ends do not necessarily mean spoilage. If the can was sealed without preliminary heating, if it was overfilled, or if it contains a highly acid fruit (especially when stored at a relatively high temperature) the ends of the can may bulge while the contents remain sterile. Notwithstanding this fact, a bulged end on a can may safey be regarded by the consumer as a warning sign, and such a product should not be regarded as merchantable.

In the popular Press warnings are sometimes given against storing food in the open can after part of the contents have been removed. The most extravagant statements are frequently made on this subject. It is obvious to one of any scientific information that an open tin is as suitable for the storage of food as a tin receptacle of any sort. The amount of tin taken up in the one or two days which it is possible to store food before it can be consumed is very much less than the amount taken up from the closed can between the time of canning the product and the time it reaches the consumer's hands.

When we think of the matter it is difficult to say in what way a tin can differs from a tin pan which is used in many homes for storing foods. The whole milk-supply of our cities is held for many hours in tin cans with loose-fitting covers, thus permitting free ingress of air. Again, it must be obvious

that bacterial spoilage does not occur more rapidly in an opened can than in a glass dish. A partly filled container is an unattractive receptacle, and for this reason there seems to be sound justification for emptying a can as soon as it is opened, but for this reason and no other.

In connection with the questions which have arisen regarding spoilage of canned foods, one has become more and more impressed upon the manufacturer in so far as it concerns the disposal and storage of the packages after they leave the hands of the canner. Damage to both the container and the contents may result from improper storage. From the point of view of the canner the position may be summarized as follows :—

(1.) Damaged goods should be separated. One leaky can may cause damage to a large number of cans and cases, especially if the case containing it should be near the top of a stack.

(2.) Canned foods should be kept dry and properly covered. Improper plumbing or bad drainage, which permits moisture to accumulate or keeps the walls and floors of storage-rooms wet, results in an atmosphere which is saturated with water and greatly promotes rusting of cans. Leaky roofs, broken windows which permit the entrance of rain, cause rusting of the cans in the vicinity of the opening.

(3.) Cases should be raised from the floor. Experience shows that in spite of precautions that are taken the floor of a store is likely to be more moist than the atmosphere of the room. This is particularly true of the ground floor.

(4.) Storage-rooms should be cool. Tin is the most insoluble of the common metals, but it is not entirely insoluble. Moreover, the tin coating on commercial tinplate is not entirely continuous. Small openings through the coating expose the steel base to the contents of the can. This precaution is most necessary for fruits and other acid foods.

(5.) The temperature of stores should be kept uniform. Sweating or condensation of moisture on the outside of the cans may occur when the temperature of the store is decidedly above that of the contents of the can.

(6.) Warehouse should be ventilated. Ventilation of a store helps to keep the atmosphere drier and in more uniform condition. Where ventilation is not present it happens that springers and perforations are more quickly developed in the top cases than in the cases lower in the stack.

(7.) Do not store too long. Although most canned foods may keep sound for many years, yet the container cannot resist indefinitely the effects of an attack upon the tinplate, either from the acidity of the contents or the rusting from without.

The curing of meats for use in the corned and pickled goods is in part a bacterial process due to the action of certain micro-organisms which grow at the temperature of the curing-cellar, 40–42° F.

In preparing a curing-brine it is customary to mix a freshly made pickle with about 10 per cent. of old brine in order to " work " the cure—or, as it is sometimes stated, " to take off the sharp taste " ; in fact, it has been found that the addition of the old brine is an aid to stimulating certain bacterial changes and actions in the brine and meat during the curing process. The composition of the curing-brine varies with the meats to be handled, but usually it is from 15 to 17 per cent. salt, with 0·25 to 0·50 per

cent. saltpetre, to which sugar is sometimes added. If the temperature is not maintained closely to the point noted, the growth of bacteria other than those required in the curing is encouraged, and it has been this factor which has introduced conditions enabling certain souring bacteria to grow in the meat during the curing process. The function of the saltpetre has long been recognized as that which gives the corned meat a reddish colour, but if the specific bacteria are not present to change the saltpetre into another compound, known as nitrite, it would not be possible to bring about the red coloration in the meat, for it is the nitrite which combines with the colouring-matter of the blood and produces a combination which gives the permanent and characteristic red colour of cured meats. The function of sugar when added to the pickle is not to sweeten, although it is an important aid in offsetting the harsher flavour of the salt; its important function lies in the fact that it supplies food for certain types of bacteria, and acts as a protective against objectionable bacterial action, and probably prevents the fermentation of and using-up of the naturally occurring sugars of the meat.

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SOME REMARKS UPON COALS AND THEIR CLASSIFICATION.

WITH SPECIAL REFERENCE TO THE LIGNITES OF THE SOUTH ISLAND OF NEW ZEALAND.

By Professor W. P. EVANS, M.A., Ph.D.

(Continued from page 170.)

IN a note to the composite table opposite page 170 it was stated that figures had been omitted as far as possible from the columns under "Chemical Characteristics" because they could but represent either the ideas of a particular classifier or the average of similar figures from a number of classifications. In order to show how widely such figures vary, a few typical instances are given below for the three main groups. The corresponding figures for the transition groups usually somewhat overlap those for the adjacent main groups.

RATIO C/H.

The limits assigned by various workers to the groups vary greatly, probably as the result of handling a restricted number of the coals of each group. The variation is most noticeable in the lignite group, where the figures for one country would sometimes exclude the majority of the coals of the same group as found in another country, although there could be no doubt about the correctness of the grouping.

Values for C/H from Four Different Classifications.

Group L.	Group B.	Group A.
Below 12·9	14·6 to 18·2	Over 22·0
12·9 to 16·0	15·0 to 17·8	Over 23·3
12·0 to 15·0	14·3 to 20·0	23·0 to 31·3
9·3 to 11·2	12·5 to 20·0	Over 26·0
(*or* 9·3 to 12·5)		

It is of interest to note that the fourth of these C/H schemes, in its first form, would exclude from the lignite group all but two of twenty-one test coals from the South Island of this Dominion, although three of those excluded contain no less than 37 per cent. of water, and all—according to every ordinary test—are undoubtedly members of the lignite group. Even in its extended form it would exclude all but six of the same coals and class them as bituminous, which they are certainly not.

Until more analyses are available, and those of one country have been carefully compared with those of others, such figures are of use only in the particular country for which they were deduced.

THE FUEL RATIO (F-C/V-M).

Here again the limits vary; though—as would be expected from the fact that numerator and denominator are more nearly equal—there is not so wide a divergence as in the case of the C/H ratio. The anthracite group is characterized by a high value, generally over 11, but sometimes falling to 8; the bituminous group by medium values, approximately 2 to 6; and the lignite group by a value which is usually less than 1, but may rise slightly higher. It must be distinctly understood that though these numbers are the values of a so-called fuel ratio, yet they are *not proportional* to the fuel values of the groups; for, while the ratio ranges from nearly 40 to about 0·5, the corresponding fuel values range only from somewhat over 9,000 to about 4,000.

There appears to be a general correspondence between the hydrogen content of coals and the amount of volatile matter given by them,* but the relation between the two quantities is evidently not one of simple proportion. Consequently, arrangement according to the C/H ratio will not correspond at all accurately with arrangement according to the fuel ratio. This want of agreement is most marked in the lignite group, but is still very evident in the anthracites. (Specific instances will be given later, when dealing with New Zealand lignites.)

SPLIT-VOLATILE RATIO.

The "split-volatile" limits, as given by Dowling, for the main groups are—A, 15 and over; B, 6 to 3·5 (or, including the transition groups in part, 13 to 3); and L, 3 to 1. The wider range possessed by this ratio in the lignite group allows it to separate the coals of the group more satisfactorily than the C/H ratio. As it treats the low-carbon coals more fairly

* Seyler is often said to have demonstrated that (the anthracites excepted) the volatile matter in coals varies with the amount of hydrogen. This is far too definite a statement, for the variation is most certainly not direct variation, and the law governing it is unknown.

by taking their high percentage of volatiles into account, its estimate of the coals is also more to be relied upon.

THE LIGNITES IN GENERAL.

Leaving for a time the subject of general classification, some little space may be devoted to the lignites, using that term as including practically all coals below the bituminous grade of the Seyler classification, or—which amounts to the same thing—as including both the black lignites (sub-bituminous coals) and the brown lignites of many American writers.

These lignites are hard to define at once simply (and satisfactorily. They are spoken of as " brown " coals—presumably because they are often not brown, being grey, or green, or yellow, or black, as occasion offers. They are called " hydrous " coals ; but what coals are truly anhydrous ? Some have attempted to define them as coals containing over 10 per cent. of water, forgetting that they may contain much less, and coals of higher rank considerably more, than the stipulated 10 per cent. Others lay stress on the fact they are attacked by solutions of caustic alkalies ; but so are coals in general : it is all a matter of quantity. They are supposed always to yield an acid aqueous distillate when destructively distilled ; but many inconsiderately give that alkaline distillate which they should leave to their betters, the coals of higher grade. Again, their solubility in phenol is quoted ; but here, too, it is merely a matter of how much. They give characteristic wax-like substances to certain solvents, or on being distilled in a current of steam ; but so also many other coals which are not lignites. Hence, in attempting to define them, we must take into account not one characteristic only, but as many as possible, realizing that the difference between coals of one group and their neighbours in the next are very slight indeed.

The writer, who has had considerable experience of the lignitic coals of this Dominion, would say that, in general, lignites are hydrous coals of varying colour ; still retaining definite traces of their vegetable origin, though not always revealing them to the casual observer ; of relatively high oxygen content ; and (as mined) of comparatively low calorific value. Usually they are freely attacked by alkalies, yielding a brownish liquid, which on being acidified gives a voluminous precipitate of acid character ; give in many cases an acidic aqueous distillate during destructive distillation ; and yield, on proper treatment, comparatively large quantities of wax-like matter. They cannot be divided sharply from other coals by any hard-and-fast definition, or by any simply drawn line on a diagram.

As coals, as potential sources of energy, they are of great and increasing importance, despite the fact that many a writer in Great Britain has hardly thought them worth mentioning until the last few years, firstly because they may be said to be non-existent in the British coalfields, and secondly because there were such large quantities of higher-grade coal to consider. On the Continent of Europe some national divisions knew them not, while to others they were—in more senses than one—an absolutely indispensable source of power. In the United States and in Canada their importance is being rapidly realized ; and in Australia, which is lucky enough to possess the " record " seams of the world—no less than 780 ft. of coal in 1010 ft. of bore—they are bound to become the chief source of power. In New Zealand also—none too well off as regards coal of any particular grade, though blessed, as in other things, with many good samples—they must be made use of to an increasing extent. Luckily, there is every prospect that our water will still be with us when our coals are no more.

FIG. 7.—Fibrous lignite (N.Z.)—water 36 per cent.—showing woody structure.

FIG. 8.—Lignite (N.Z.)—water 21 per cent.—showing incipient banding and change towards prismatic fracture.

As a group the lignites have been given a much worse name than they deserved, chiefly because they gave some trouble when people attempted to use them in just the old way to which they had become accustomed to with bituminous coals. But, like each dog, each coal has its day. How many remember that, in our very own England, Parliament petitioned the King to prevent the use of "coles," and that in consequence proclamation was made against their further use, "lest the health of the knights of the shire should suffer during their residence in the metropolis"? How many know that nearly fifty years earlier the City of London itself petitioned Parliament "on account of two nuisances or offensive commodities which were likely to come into great use and esteem; and that was, Newcastle coles in regard of their stench; and hops in regard they would spoyle the taste of drinck and endanger the people"? Yet these things happened. We are also apt to forget that even anthracite had to make a struggle before it could convince people of its good character. Now, however, we clamour for more anthracite, and even attempt to produce it artificially.

Lignites will not have such a struggle, because we know that, whether they be good or whether they be bad, used they must be, and that to the utmost. Quite apart, however, from the necessity of using them, they are well worth using. "Lignites, raw, or dried, or carbonized, can be burned in a suitable furnace as readily as anthracite; can be burned without soot, or smoke, or danger." Further, "Lignites Limited" are a large concern in the coal world—just how large few people realize.

Measured in hundred-thousand-million tons, the total reserve of known coal of all sorts is approximately 74; and of this total the bitumites make up 39, the lignites 30, and the anthracites the remaining 5. The lignites therefore represent no less than 40·5 per cent. of our total coal-supply. America possesses the lion's share, having almost 94 per cent. of the whole; Asia comes next—a very poor second—with about 3·7; Europe and Australasia, using the latter term in its widest sense, each about 1·2; and Africa last, with a practically negligible amount. Luckily for the British Empire, about one-quarter of America's huge share lies in the ground of Canada. Such figures give cause for thought. It may perhaps be said that they refer to low-grade coals only, and they do; but, of coal of all sorts, America has over 51 out of the total 74 above referred to.

Surely it is plain that waste of coal is a national sin. Whatever America may feel justified in doing, other countries must make the best use of their rapidly dwindling supplies, and at the same time see to it that all other available sources of energy are employed to the best advantage. It is sad to think that in some of our New Zealand lignite-mines well over half of the coal cut is absolutely wasted. Part of this waste is due to faults at the mine, part is due solely to the existing conditions of transport, but a very great part is due to the ignorance of the public with reference to lignitic coals. If the stokers of household fires would remember that, in nearly all ordinary cases, a mixture of lignite and bitumite is preferable to bitumite alone, not nearly so much of our splendid West Coast coal would be belched forth from the chimney-tops, and much less would go half-used into the ash-pans. They should also remember that whenever a moderate but steady fire is required for a long time, as in heating a water-supply for radiators, the lignite, if of fair quality, is altogether better than the fiercer bitumite; it will do the work, make no fuss, and require practically no attention; its ash, moreover, makes excellent paths, and weeds do not like it. The use of a fierce bitumite (and those of New Zealand are really fierce) to heat the low-temperature furnace of a water-

FIG. 9.—Lignite (N.Z.)—water 21 per cent.—showing two different types of coal. The two types carry different amounts of water, but are otherwise very similar in composition.

FIG. 10.—Super-lignite (N.Z.)—water 8·2 per cent.—showing two types of coal.

supply is as stupid a performance as the use of a thoroughbred steeplechaser to drag a wheelbarrow, and the result in each case much the same. The high-spirited horse first sulks, and then expends some of his surplus energy in smashing the barrow; the fierce gas-coal, after ill treatment by lavish use of the poker, uses its surplus energy in burning out the grate. There is—or ought to be—sufficient real work in New Zealand for her first-class coals without such stupid waste. This, however, is an article on the classification of coals, and not the common-sense use of them.

SUBDIVISION OF THE LIGNITES, AND SOME OF THE DIFFICULTIES ATTENDING IT.

The lignites are found in such variety of colour, texture, hardness, and composition, that subdivision—though absolutely necessary—becomes a matter of great difficulty. If minor characteristics be taken into account, then even the coal from one seam may appear to belong to several varieties. The chemical composition ranges between wide limits; but still these limits may be set, though, of course, quite arbitrarily. When once the limits are decided upon, then further subdivision must, in the case of the lignites, depend chiefly upon physical characteristics. Such characteristics naturally make different appeals to different observers; what is one man's goose is another man's swan; and hence the great variation that is to be found in the subdivision of these coals.

At times it is hard to believe that the proposers of such subdivision schemes have ever handled a lignite at all. For instance, one well-known text-book on fuel contains the following astounding statement: "The chief varieties of lignite are (1) caking coal, (2) splint coal, (3) cannel coal." The only charitable explanation that can be given for such misstatements is that the proof-reading was very careless, and that the whole sentence ought to have been transferred to an entirely different section of the work; but the context hardly agrees with this view. Further instances of similar mistakes, worse in effect because less evident to the reader seeking information, are to be found scattered broadcast. The nomenclature used in connection with the lignites, though perhaps not worse than that in connection with other coals, is sadly in need of a complete overhaul. The black lignites are becoming known as the sub-bituminous coals (in America especially), while the term should surely be applied to those only whose position entitles them to claim close relationship with the bituminous coals proper. The same term is used by the majority of writers outside the United States to denote this restricted transition-group. Others refer to the true sub-bituminous coals as per-bituminous, although they do not, as is suggested by the name, show the bituminous characteristics to a more marked degree than the bitumites proper, and are below them in grade. The class names must of necessity vary somewhat from country to country and from time to time; but need they include such horrible examples as "xyloid lignites"? The class-names, however, can never be quite satisfactory, because they cannot express within the narrow limits of such names all the various characteristics which demand the class.

In the table of general characteristics already given (opposite p. 170) the "ordinary" lignites are divided into four* subgroups (or varieties)

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*Many would add two more varieties—"common lignites" and "canneloid lignites." The first of these subdivisions appears to the present writer to be lacking in character; its characteristics, as given, are not in any way distinguishing. The second, according to the scheme under consideration, falls into the "special" family, and is but poorly represented in New Zealand.

FIG. 11.—Lignite (N.Z.)—water 17·5 per cent.—showing small prismatic fracture and very little tendency to form weathering-cracks.

FIG. 12.—Completely carbonized resinous wood (from N.Z. lignite) showing all structural details.

only, as further subdivision seems unnecessary in the case of the New Zealand examples. It must, however, be clearly understood that these divisions are not mutually exclusive, it being often a matter of choice whether a lignite shall be placed in one division or another. Only a careful estimation of the values to be assigned to the various determining factors can at last decide the best position for a particular coal.

The physical characteristics upon which the subdivision of the lignites is based are in themselves sufficiently definite for such use; but their application, as has been pointed out already, is dependent upon the physical characteristics of the user. Even a crack may appear decidedly curved to one pair of eyes and fairly straight to another; what is but dark grey to one may be decidedly black to another. Quite apart from such slight difficulties, however, the coals themselves are by no means constant in external character, and consequently a scheme of subdivision may prove perfectly satisfactory in one country and just as troublesome in another. Two physical characteristics—namely, cleavage and weathering—may be taken as an example of all. Firstly, the lignites are generally divided fairly sharply from the bitumites by the fact that they do not show the prismatic fracture surfaces characteristic of the higher group, even those lignites which lie nearest to it having a conchoidal fracture. Yet, when one tries to apply this method of separation to the coals of New Zealand, one finds, on the one hand, lignites with good prismatic fracture, and, on the other hand, really first-class bitumites with distinctly conchoidal fracture as a dominant feature. (See fig. 11, and fig. 6, p. 167.) One or two lignites from the South Island of the Dominion actually go so far as to imitate successfully the micaceous fracture of an anthracite. (See fig. 2, page 163.)

Campbell's well-known system of subdivision for the lignite class in the United States is based to a large extent upon "weathering," assuming that such weathering "depends entirely upon the degree of transformation or metamorphism that it [the coal] has undergone." In the *résumé* at the end of his paper he says: "Manner of weathering divided into two classes—(*a*) Irregular breaking in sub-bituminous coal as opposed to cleaving into prisms in bituminous coal, and (*b*) separation along bedding-planes into plates in sub-bituminous coal." This weathering cleavage along bedding-planes, however, is very often conspicuous by its absence in the black lignites of New Zealand, many of which—although containing over 30 per cent. of water—weather comparatively slowly, and then show curved cracks only. The system, which seems to work quite well with the United States lignites, is often not applicable to those of New Zealand. The New Zealand coals, taken as a group, appear determined to show their insularity. While lignitic in appearance, they may be most bituminous in chemical character; or, again, while distinctly lignites as regards their composition, they may masquerade as bitumites of standing. To some extent they have their counterpart in the United States, as would be expected from the vast area covered by the lignite-beds of that country. That this is so is clear from the statement of Campbell himself, a statement so particularly applicable to our local conditions that it may be given in full: "The development of cleavage," he writes, "is not, however, an infallible guide to the present character of the coal, for time is an element that enters largely into the transformation, and frequently the same result may be accomplished by a powerful

force acting quickly that would take a weak force a much longer time for its accomplishment. Therefore some coals very young geologically but subjected to very strong dynamic forces may have cleavage as well developed as the very oldest Carboniferous coals, but the time may not have been sufficient for the material to have been changed into bituminous coal."

Judging by some of our West Coast coals, it must also be possible for a coal to become very highly bituminous without at the same time developing the cleavage characteristic of its quality. It is therefore all the easier to appreciate Campbell's further statement that "cleavage alone cannot be used as a criterion for the separation of bituminous from sub-bituminous coal, but it is of great assistance when used with discretion." After all, such cases as those just mentioned are merely so-many witnesses to the fact that there are no sharp lines of division between the various groups. The difficulties experienced in attempting to separate coals from different localities do not affect the validity of the groups, but simply show how closely they are united. In criticizing Campbell's method, Grout says, "The properties are too indefinite. Any and all classifications of coal must show gradation between types, and it is impossible to criticize the fact of gradation; but it seems as if there might be some objection to using, as criteria for a classification, qualities almost incapable of quantitative expression."

It must be conceded that the three points used by Campbell—(1) cleavage, (2) fracture on drying, (3) separation into thin plates on weathering—are not capable of quantitative measurement, and are particularly liable to errors of personal equation. Nevertheless they are of use in dealing with those lower-grade coals whose separation into subgroups, though certainly desirable, is almost impossible without the aid of physical properties.

TYPICAL NEW ZEALAND LIGNITES ARRANGED ACCORDING TO VARIOUS RATIOS.

The twenty-one lignites used in the following tests may be looked upon as normal in their development; for, apparently, they have not been altered in any way by igneous intrusives. No. 9, however, must be taken with a certain amount of caution, since it probably belongs to the "sapropelic" family as much as to the "ordinary" or non-sapropelic family, and is certainly a "drift" coal. The remaining twenty, all "ordinary" coals, cover a wide range, both geographically and in chemical composition. They include coals from the extreme north to the extreme south of the South Island; from the east coast to the western foothills of the main dividing-chain. As far as quality is concerned, they range from super-lignite of really high type to very wet and fibrous lignite, and may therefore be considered a typical set of samples. They were, indeed, chosen as representative.

The table following shows their order as given by the various factors of classification named. As the ultimate test of any coal is its power to work, the calorific values, as determined by the bomb calorimeter, are given also. Any really successful classification factor should place the coals in much the same order as their calorific value does, and a glance at the table is sufficient to show that most of the factors used do anything but this.

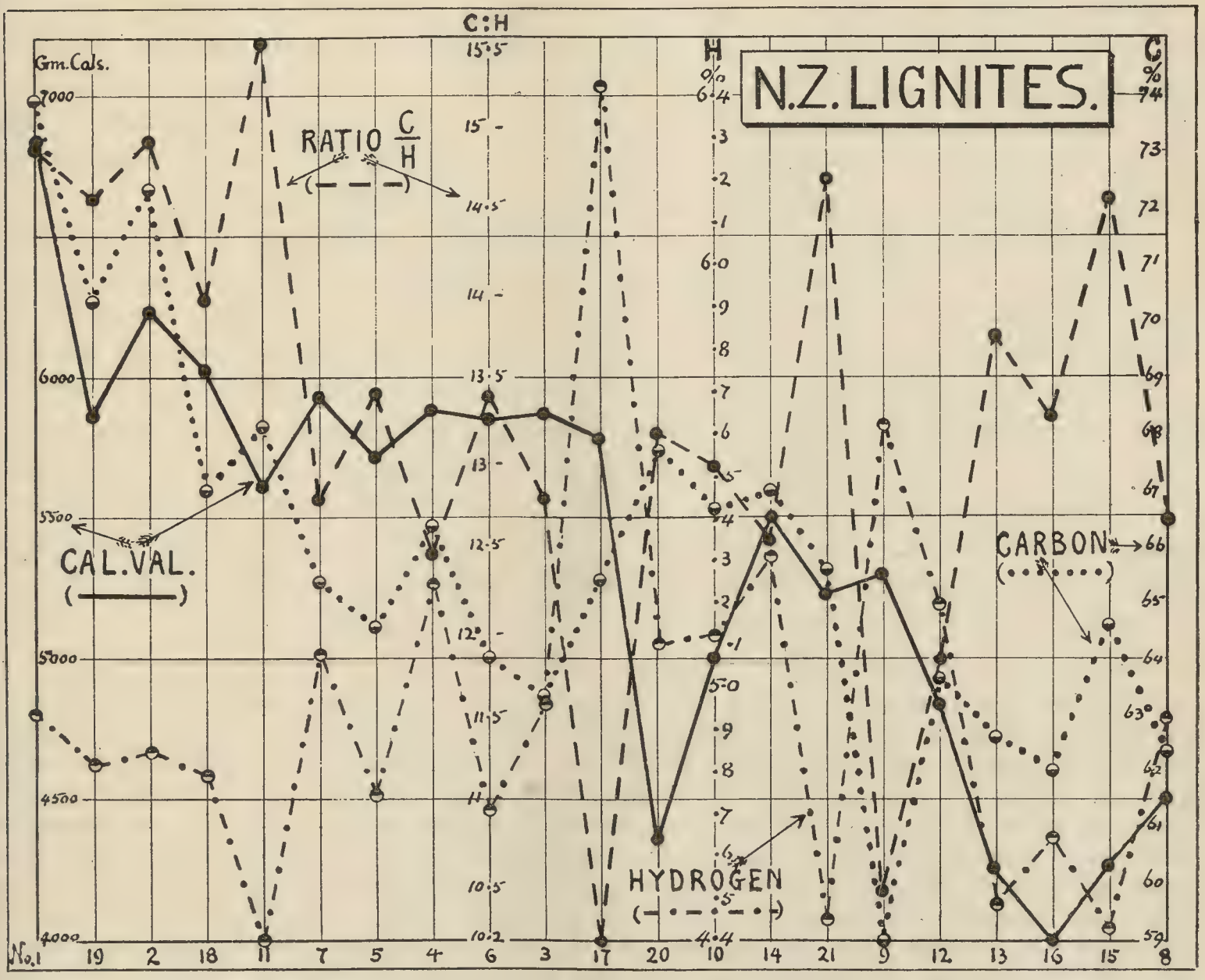
Table showing Positions of Twenty-one New Zealand Lignites when arranged according to various Bases of Classification.

Fixed Carbon Percentage in Raw Coal.	Ratio of Fixed Carbon to Volatile Matter.	Ratio of Carbon to Hydrogen.	Coal-substance Percentage in Raw Coal.	Total Carbon Percentage in Raw Coal.	Split-volatile Ratio.	Ratio of Carbon to (Oxygen plus Ash).	**Calorific Value.**	Water Percentage in Raw Coal (increasing).	Ratio of Total Carbon to Volatile Carbon.	Ratio of Total Carbon to Fixed Carbon (increasing).
1	19	11	1	1	1	2	**1**	1	19	19
19	1	2	2	2	19	1	**2**	6	11	18
2	2	1	6	19	2	14	**18**	7	18	20
18	20	21	3	18	18	4	**7**	9	20	1
11	18	19	4	7	7	19	**4**	18	1	2
7	11	15	18	4	5	10	**3**	3	2	21
5	10	18	7	6	6	7	**19**	4	21	11
4	5	13	5	11	11	5	**6**	5	7	13
6	7	5	19	5	4	11	**17**	19	10	7
3	13	6	11	3	3	20	**5**	2	5	10
17	17	16	17	17	17	6	**11**	17	6	3
20	4	20	14	14	9	3	**14**	11	3	6
10	6	10	9	9	10	18	**9**	21	17	5
14	3	7	10	10	14	17	**21**	14	4	17
21	12	3	12	12	21	21	**10**	6	9	4
9	14	8	16	20	12	13	**12**	12	12	12
12	21	14	20	21	20	15	**8**	16	14	9
13	9	4	21	15	13	12	**20**	13	16	14
16	15	12	8	13	16	8	**15**	15	15	16
15	16	9	15	16	15	16	**13**	8	13	15
8	8	17	13	8	8	9	**16**	20	8	8

Tabular statements such as the above are capable of misuse. Coincidences, it must be remembered, are divisible into two classes—(*a*) those which may be called mathematical coincidences, and (*b*) those which are nothing but coincidences. The fact that one particular list shows several coincidences with what is looked upon as the test list is not necessarily evidence in its favour. A simple instance will make this point clear. Suppose a set of twenty-six coals to be properly graded when in alphabetical order. A second classification scheme might return them in the order *b*, *a*, *d*, *c*, *f*, *e*, *h*, *g*, and so on. This second list would show not a single coincidence with the first, but it would be an extremely good one, and, in all probability, better than others showing many coincidences. The surest method of comparing the results given by the various factors is to plot the factor values as curves, preferably with approximately equal ranges, and then see which curve most closely follows the test curve. It would make too great a demand upon space to reproduce such curves for all the arrangements mentioned above, and a single diagram showing all at once becomes rather confusing. Hence it must suffice to state that, of the curves corresponding to the factors used, those for the "split-volatile ratio," the "total carbon," and the "coal-substance" are much closer generally than

any of the others to the calorific-value curve. Between these three there is but little difference. The fact that the coal-substance curve so closely follows the curve for calorific values shows that, in the limited field of the South Island, the determination of water and ash alone is capable of giving a very fair estimate of the value of the coal. Such an elementary method of comparison would, however, fail with coals of wider range, and is not to be looked upon as always applicable even in a small field. The approximate parallelism of the two curves is, of course, merely the graph's method of informing us that the calorific value of the "coal-substance" is approximately constant throughout the range under consideration. It has been often assumed that this value is constant for *all* coals, but actual determinations of calorific value appear to prove the assumption unjustifiable.

As an instance of this method of comparison the curves for the C/H ratio, percentage of carbon, and percentage of hydrogen, with the calorific-value curve as a standard, are reproduced in the graph below. This particular ratio (C/H) has been chosen in order to illustrate its failure when dealing with comparatively low-grade coals. The curves for carbon and hydrogen show the reasons for that failure. A coal (see No. 15) may have both carbon and hydrogen low and yet return a high C/H ratio; on the other hand (see No. 17), both carbon and hydrogen may be satisfactory and still their ratio be comparatively low.



GRAPH SHOWING FAILURE OF THE CARBON TO HYDROGEN RATIO IN THE CASE OF THE LIGNITES.

The graph shows very clearly that the ratio C/H, good as it is for the bitumite group in general, is *not* applicable to the lignites, with their lower carbon and extremely variable hydrogen.

For coals of the lignite group some modification of the ratio is needed. Instead of the simple ratio C/H, the writer thinks that some expression of the type $\frac{C}{H} + a\,(H-h)$ would be more satisfactory. If, in the modifying term, H is the percentage of hydrogen in the coal considered, and h a standard percentage (approximately 5·2), then a proper value given to the constant a would reward the coal for possessing a high percentage and penalize it for a low percentage of hydrogen. For a limited field, some such formula, or one of the more sensitive type $\frac{C}{H} + aH\,(H-h)$, can easily be made fairly satisfactory; but it is doubtful if any *one* set of constants would satisfy the demands made by all low-grade coals.

DIAGRAMMATIC REPRESENTATION.

The simple tabular form generally used to express the percentage of carbon and hydrogen contained in the coals considered is sometimes replaced by a system of co-ordinates*—usually rectangular.

Evidently, if the percentage of carbon be shown by distance from the carbon axis, and the percentage of hydrogen by distance from the hydrogen axis, the point so arrived at for the position of any particular coal also shows the ratio C/H for that coal.

Such diagrams, however, useful as they undoubtedly are owing to their rapid and forceful appeal to the eye, do not often advance matters beyond the stage of the simple table. They can but represent diagrammatically the results already obtained; and, as long as we remain ignorant of the relative values to be assigned to the elements plotted in them, are apt to inspire a feeling of confidence that is not altogether warranted.

The diagram, however, has one very definite advantage over the ratio as such; it not only defines the quotient, but also strictly limits both the numerator and the denominator. The ratio of 80 to 5 is also the ratio of 64 to 4; but the diagram, while admitting a coal with 80 per cent. of carbon and 5 of hydrogen, might yet exclude a coal with 64 per cent. of carbon and 4 of hydrogen. This is a very important advantage, and is sometimes overlooked. The diagram has the further advantage that on it one may "see at a glance the relation of a sample to the whole series and the common range of variation." A table of ratio-values may give some of this information; and—if accompanied by limiting values for the terms of the ratio—all of it; but in neither case can it do so at a glance.

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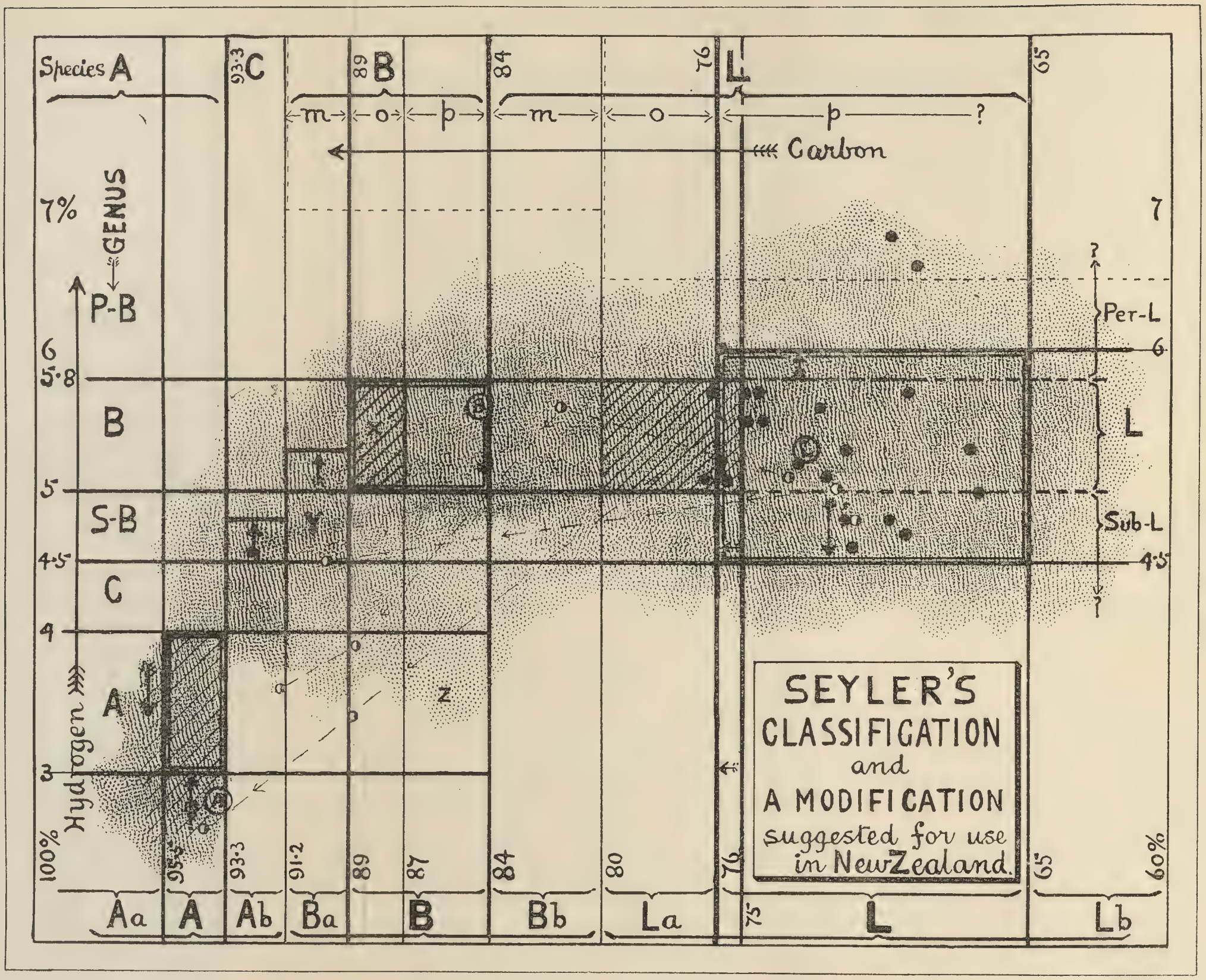
* Some few workers, wishing to include oxygen as well as carbon and hydrogen among the determining factors, have, unfortunately, introduced the idea that their carbon-hydrogen-oxygen system as illustrated in a *plane* diagram is a three co-ordinate system. It is, however, evident that when the position of a point on a plane is settled with reference to two axes in that plane at right angles (or any angle) to one another that point is completely fixed and quite independent of any other measurements that may be made. Simply from the standpoint of analysis—the coal substance being taken as containing carbon, hydrogen, and oxygen only, and *oxygen determined by difference*—it is clear that the oxygen axis, if introduced into the diagram, can be of use only in enabling one rapidly to recognize this *already determined* oxygen *difference*. Other workers appear to think that by using the axial system they entirely avoid the use of ratios. In reality, the use of rectangular co-ordinates implies the use of the ratio between the quantities plotted on the diagram. In a carbon-hydrogen diagram, for instance, the upper and lower limits of the C/H ratio for any particular group are definitely given by the four lines bounding the field of that group. The ratio may not be so evident, but it is there.



COMPOSITE DIAGRAM SHOWING (1) SEYLER'S SCHEME OF CLASSIFICATION, AND (2) THE SAME AS MODIFIED BY THE WRITER FOR USE WITH NEW ZEALAND COALS.

In the diagram the horizontal (hydrogen) and vertical (carbon) lines show the boundaries of the principal sections—genera and species in the original groups in the modified scheme. The hydrogen scale is five times as open as that for carbon. Where—in the modification—small readjustments of the boundaries have been made, these are indicated by arrows pointing from the original to the new position. The ortho-species of Seyler's genera are diagonally lined. The main groups of the writer's scheme are bounded by double lines. The half-tone shading indicates roughly those fields in which coals are most likely to be found, and the depth of the shading gives an indication of the frequency of their occurrence. The letters at the top and sides of the diagram refer to Seyler's classification; those at the bottom to that of the writer. A, B, L, P-B, S-B, and C (top and left) stand for Anthracite (or Anthracitic), Bituminous, Lignitious, Per-Bituminous, Sub-Bituminous, and Carbonaceous respectively; while *m*, *o*, and *p* (top) stand for meta-, ortho-, and para- respectively. The letters at the bottom of the diagram are the group symbols already given on page 169. The percentages of carbon and hydrogen limiting the various rectangular fields are given at the margin, and any intermediate percentage may be derived from the appropriate scale.

[Note on the carbon limits assigned to the groups: To those not well acquainted with the distribution of coals on the carbon scale, it may appear that the subgroups, though spoken of as small, are relatively large. This is true as far as regards the actual range of carbon allotted to them, but not as regards their numbers. The coals are by no means evenly distributed along the carbon line; they congregate into families between the group percentages. For instance, out of 207 definite lignites the analyses of which can be fairly relied upon, 163—or 78·7 per cent. of the whole number—lie between the 65 and 76 per cent. lines bounding the main lignite group (15 only are super- and 29 sub-lignites). Somewhat similar conditions are found in the bitumite and anthracite portions of the line. We travel, as it were, along a coal-road, passing through three large towns, while the intermediate country districts are but thinly populated.]

Grout's classification, referred to in a previous section, furnishes a simple example of the method. Grout uses the ratio of fixed carbon to total carbon (each term being calculated on to the pure coal), considering that "the two variables are then of one type." This assumed coincidence of type may be questioned. The so-called fixed carbon is not all carbon, and the two variables are not got by equally exact methods. His diagram will not be reproduced here, but its scope can be deduced from the limiting values assigned to the main rectangular fields. These are :—

		Per Cent.
Anthracite	Fixed carbon	Over 93
Semi-anthracite	Fixed carbon	83 to 93
Semi-bituminous	Fixed carbon	73 to 83
Bituminous—		
High grade	Fixed carbon	48 to 73
	Total carbon	82 to 88
Low grade	Fixed carbon	48 to 73
	Total carbon	76·2 to 82
Black lignite	Fixed carbon	35 to 60
	Total carbon	73·6 to 76·2
Brown lignite	Fixed carbon	30 to 55
	Total carbon	55 to 73·6

The grouping in Grout's diagram is excellent, so far as the examples given are concerned. They are, however, far too few to try out the method; for instance, only six lignites in the black and six in the brown group. No wonder that "the brown lignites are well distinguished from the black." At times it is somewhat hard to grasp the meaning underlying the words used by Grout, as when he says, "To avoid the ultimate analysis, one must consider the pure coal as the sum of fixed carbon and volatile matter instead of the sum of carbon, hydrogen, and oxygen." His scheme *must* use ultimate analysis; and the main objection to it is that it uses ultimate and proximate analyses as of equal accuracy, or, as Grout himself says, "of one type." It is, however, not well to draw particular attention to the few blots on what is really a very good picture of the whole field of coal.

SEYLER'S CLASSIFICATION EXTENDED, AND THE POSITION OF THE NEW ZEALAND LIGNITES.

When comparing analyses of lignites from various parts of the world, the writer had occasion to make a scale diagram of Seyler's classification, extended so as to include the whole range of para-lignitious coals. This scale diagram appeared to be more suggestive than the simple tabular form usually given to the classification, and is therefore reproduced here, both to show the scope of the excellent scheme and as an actual instance of the graphic method of representation. In order to save space, and at the same time to show quite clearly the connection between the original classification of Seyler and the writer's modification, the latter has been superimposed upon the former in the diagram as here reproduced.

The nomenclature introduced by Seyler, although it may appear to be complex, is really simple, because strictly ordered. The ortho-coals of a genus are those which he considers contain the percentage of hydrogen, and also the percentage of carbon, characteristic of the genus. The

prefixes "per-" and "sub-" signify a hydrogen content above and below the normal respectively, the carbon meanwhile remaining normal. The prefixes "meta-" and "para-" imply a decrease and increase respectively in the oxygen content, while the hydrogen remains normal; which is, in effect, the same as saying that they represent an increase and decrease respectively in the carbon content. A coal is ranked by "genus" and "species," the "genus" being determined—in all but the lignitious coals—by hydrogen, and the "species" by carbon. Thus a coal in the rectangle marked X on the diagram is in the bituminous genus and in the ortho-section of the bituminous species. It is therefore an ortho-bituminous coal; it represents the typical bitumite. A coal in the rectangle marked Y is a sub-meta-bituminous coal; while one in the rectangle marked Z, being in the anthracite genus but para-bituminous by species, is a pseudo-anthracitic-sub-para-bituminous coal, or a sub-para-bituminous pseudo-anthracite. (In the writer's modified scheme the X coal would still be the typical bitumite; the Y coal a super-bitumite; and the Z coal merely a bitumite of abnormally low hydrogen content. His system has neither the range nor the accuracy of Seyler's, but yet seems to be wide enough for use in New Zealand, where the bitumites are really very restricted in range, and the anthracites practically non-existent. It has the advantage of being very simple, and is still quite in accord with the standard Seyler classification.) Seyler's names are really portmanteaux packed with information regarding the position and general properties of the coals. It must be granted that in some instances the names chosen are apt to be confused with similar names applied to different kinds of coal; but, considering the state of coal nomenclature in general, it is very difficult to see how such confusion could have been avoided. The classification, in the opinion of the present writer, is the best yet proposed, and certainly marks a great step in advance by making more rational use of the hydrogen content of the coal-substance than had been the custom. It seems to have given satisfaction to all who have really taken the trouble to use it in connection with high-carbon coals, and for low-carbon coals it was not primarily intended.

In its ordinary form Seyler's classification is bounded by the 75-per-cent. carbon line—very often, indeed, by the 84-per-cent. line marking the lower limit of the bituminous coals. In the diagrammatic form it has been extended to include all the lignitious coals of Seyler—that is, all coals with less than 84 per cent. of carbon. It will be noticed that of the twenty-two typical New Zealand lignites—many of very high class—shown on the diagram by small filled circles according to the percentages of carbon and hydrogen in their coal-substance, two are ortho-lignitious, and fourteen para-lignitious. Two fall in the per-lignitious section, and four in the sub-lignitious. (The remaining coals, shown by partly filled circles, are lignites more or less altered by igneous intrusives, and are not considered in this article.) It was the position occupied by these lignites and some two hundred others from different countries that led the writer to modify slightly the boundaries originally given to the lignite region.

Sometimes an objection is raised to Seyler's nomenclature on the ground that the group-averages do not all fall in the ortho-sections of the corresponding fields. The objection is not valid. The ortho-position merely denotes the type—more or less the ideal—for the particular field, and the ideal coal does not of necessity correspond any more closely with the average for that field than does the average loaf of a particular market

with the ideal bread possible in that market. Seyler's limits are all fairly high, because he had to deal with the high-carbon coals of Wales, and hence even the bitumite average (so called) does not reach his standard, but falls well down in the para-species. As a matter of fact, most comprehensive schemes classify the meta-lignitious coals (carbon from 84 to 80 per cent.) as belonging to the transition group between bitumites and lignites; indeed, if the writer reads Seyler correctly, that is his opinion of them; they are just below the normal bitumites, and include practically all those coals which, in many other classifications, are called "sub-bituminous." They form the sub-bitumite group of the modified scheme. Most of the lignites whose ultimate analyses are available in reliable form fall either in the para-section of Seyler, or in the lower portion (as regards carbon) of the ortho-section. Clarke's average* for lignites, which corresponds closely with that for New Zealand lignites, although none of them were included in it, also falls in the para-section. A comparatively slight alteration of the limiting verticals—carbon percentages—would allow the excellent classification of Seyler to be used throughout the whole of the British Empire, instead of being limited, as at present, to Great Britain.

Such a modification is easy as far as concerns the carbon content defining these coals as a group, but when it comes to subdividing them into classes the difficulties are very great, for hydrogen alone—Seyler's criterion—does not sufficiently satisfy the requirements; physical properties must be taken into consideration.

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* Such group averages must be looked upon as rough approximations only. The accuracy of any particular group average depends upon (1) the limiting values assigned to the group, (2) the accuracy of the various analyses involved, (3) the number of analyses available, and (4) the distribution of those analyses among the different varieties composing the group. Errors due to the first and second of these factors will no doubt ultimately disappear—the group limits will be definitely fixed by convention, and the analytical methods employed become standardized; but those due to the third and fourth will remain much longer. It by no means follows that an average derived from one hundred analyses is more closely representative of a group than one derived from only fifty analyses. The first average will be the better if, and only if, the various coals involved are at least as fairly divided among the varieties composing the group as are the coals used in the derivation of the second average.

The group-averages quoted already (p. 87) are those given by Clarke (*The Data of Geochemistry*, ed. 4, p. 763), though that for the lignites has been recalculated in order to give due weight to each of the three partial averages included in it. They give a fair outline of the differences in composition between the various groups, but cannot be looked upon as real averages in the mathematical sense. The hydrogen percentage (2·8) given for the anthracite group appears to the writer to be too low for the group as a whole. In any case, being derived from sixteen analyses only, it can hardly be representative of the world's anthracites. The South Wales anthracites would give an average of approximately 4 per cent., and the average for the North American anthracites whose analyses are available is well over 2·8. Some of the graphitic coals —for instance, those of the Ural districts of Russia—contain less than 1 per cent. of hydrogen, and the inclusion of one or two of such coals in a total number so small as sixteen would evidently lower the average unduly. It is the difficulty of giving proper weight to each of the various types included in a group that makes the calculation of a so-called "world average" practically impossible. The figures given by Clarke as averages for carbon and hydrogen in the lignite group (72·72 and 5·37 respectively) agree quite well with the averages for New Zealand lignites (72·29 and 5·37 respectively); but, on the other hand, they differ widely from the averages for many other lignite fields (compare Germany, approximately 68·0 and 6 0 per cent.; Russia, approximately 62 and 5 per cent.; Italy, 70 and 6·1 per cent.).

Averages for the coals—of one group, naturally—from a particular field, and also, though to a much less degree, for the coals of a particular country, have no doubt a definite value, but it is very questionable whether the same can be said for the so-called "world averages."

ULTIMATE ANALYSES OF AND DISTRIBUTION OF SULPHUR IN SOME TYPICAL NEW ZEALAND LIGNITES.

No.	Name.	Proximate Analysis and Calorific Value of Coal as received.							Ultimate Analysis of Dry Coal.						Distribution of Sulphur in Dry Coal.		Composition of Coal-substance (Organic).					Percentage of C-S in		Remarks.	
		Water.	Volatile Matter.	Fixed Carbon.	Ash.	Sulphur.	V.M./F.C.	Cal. Value. (cals./gm.)	Carbon.	Hydrogen.	Oxygen.	Nitrogen.	Sulphur.	Ash.	Organic.	Inorganic.	Carbon.	Hydrogen.	Oxygen.	Nitrogen.	Sulphur.	Dry Coal.	Wet Coal.		
1	Puponga ..	11·68	37·8	48·6	1·95	0·83	0·78	6830	73·90	4·94	17·04	0·98	0·94	2·20	0·87	0·07	75·62	5·06	17·32	1·11	0·89	97·7	86·3		Normal lignites, apparently unaltered by volcanic action, but evidently, in many cases, compressed by folding.
2	Inangahua ..	17·41	38·4	43·5	0·67	2·76	0·88	6225	72·39	4·85	17·50	1·11	3·34	0·81	3·23	0·11	73·06	4·90	17·43	1·35	3·26	99·1	81·8		
3	Avoca (A.) ..	15·95	45·8	32·1	5·22	5·08	1·38	5860	63·39	4·94	18·25	1·17	6·04	6·21	6·04	Nil	67·59	5·27	19·46	1·24	6·44	93·8	78·8		
4	,, (B.) ..	15·98	45·1	33·5	5·40	5·17	1·31	5870	66·34	5·24	14·75	1·08	6·17	6·42	6·17	Nil	70·89	5·60	15·76	1·15	6·59	93·6	78·6		
5	,, (C.) ..	16·32	43·3	33·7	6·71	4·78	1·29	5710	64·53	4·74	15·91	1·10	5·71	8·01	5·71	Nil	70·14	5·15	17·30	1·20	6·21	92·0	77·0		
6	,, (D.) ..	14·08	45·6	33·4	6·94	5·17	1·37	5845	64·01	4·71	16·08	1·10	6·02	8·08	6·02	Nil	69·64	5·12	17·48	1·20	6·55	91·9	79·0		
7	,, (N.) ..	14·50	44·2	34·8	6·59	5·44	1·27	5920	65·37	5·08	14·82	0·66	6·36	7·71	5·59	0·77	71·43	5·55	16·19	0·72	6·11	91·5	78·3	Water originally 15·30 %	
8	Coal Creek Flat (R.B.)	37·36	40·8	18·0	3·91	0·41	2·27	4510	62·37	4·92	24·60	1·22	0·65	6·24	0·65	Nil	66·52	5·25	26·23	1·30	0·69	93·8	58·7		
9	Coal Creek Flat (H.C.)	14·50	47·2	26·4	11·88	0·47	1·79	..	58·94	5·61	20·33	0·67	0·55	13·90	0·44	0·11	68·54	6·52	23·64	0·78	0·51	86·0	73·5		
10	Taratu ..	27·52	37·6	30·6	4·34	3·55	1·22	5000	66·68	5·12	16·79	0·53	4·90	5·98	4·28	0·62	71·39	5·48	17·97	0·57	4·58	93·4	67·7		
11	Mossbank ..	20·93	39·7	36·4	2·99	0·33	1·09	5605	68·12	4·40	21·93	1·36	0·41	3·78	0·41	Nil	70·79	4·57	22·79	1·41	0·43	96·2	76·1		
12	Homebush ..	28·98	39·4	26·4	5·22	0·44	1·49	4845	63·58	5·20	22·48	0·77	0·62	7·35	0·48	0·14	68·73	5·62	24·05	1·08	0·52	92·5	65·7		
13	Mount Somers	36·27	33·1	25·0	5·67	2·57	1·32	4260	62·68	4·48	19·40	0·52	4·03	8·89	3·00	1·03	69·58	4·97	21·53	0·58	3·33	90·1	57·4		
14	Charleston ..	26·15	43·8	28·8	1·26	6·04	1·52	5510	67·06	5·31	17·45	0·30	8·18	1·70	7·38	0·80	68·78	5·45	17·79	0·41	7·57	97·5	72·0		
15	Benhar ..	36·98	38·1	21·1	4·49	0·11	1·80	4265	64·65	4·43	23·63		0·18	7·11	0·18	Trace	69·60	4·77	25·44		0·19	92·9	58·5		
16	Mataura ..	35·41	39·1	21·1	4·38	0·14	1·85	4005	62·00	4·64	25·95	0·42	0·21	6·78	0·21	Trace	66·51	4·98	27·64	0·65	0·22	93·2	60·2		
17	Kaitangata (A.)	19·83	43·1	32·3	4·71	0·12	1·33	5785	65·40	6·42	21·48	0·67	0·15	5·88	0·09	0·06	69·53	6·82	22·83	0·71	0·10	94·1	75·4		
18	,, (B.)	15·15	38·0	40·4	6·54	0·42	0·94	6015	66·99	4·79	19·11	0·91	0·49	7·71	0·43	0·06	72·65	5·19	20·72	0·98	0·46	92·2	78·3	Water originally 15·90 %	
19	Linton ..	17·10	33·3	43·9	5·71	0·31	0·76	5850	70·37	4·82	17·56		0·37	6·88	0·26	0·11	75·66	5·18	18·88		0·28	93·0	77·1		
20	Glenroy ..	37·55	28·3	31·3	2·80	0·46	0·90	4355	67·70	5·10	21·98		0·74	4·48	0·74	Trace	70·88	5·34	23·01		0·77	95·5	59·7		
21	Nightcaps ..	25·52	43·3	27·6	3·62	0·26	1·57	5235	65·63	4·45	24·71		0·35	4·86	0·29	0·06	69·03	4·68	25·99		0·30	95·1	70·8		
22	Steventon (M.)	22·90	33·9	40·3	2·90	0·45	0·84	5615	68·26	4·62	22·78		0·58	3·76	0·55	0·03	70·95	4·80	23·67		0·57	96·2	74·2	Approx. 16 ft. from sill.	Lignites altered by igneous intrusions.
23	,, (3A)	18·64	28·3	37·1	16·03	0·57	0·76	4980	57·50	3·98	18·12		0·70	19·70	0·56	0·14	71·73	4·96	22·61		0·70	80·2	65·2	Approx. 12 ft. from sill.	
24	,, (D2)	3·30	13·2	66·3	17·20	1·44	0·20	..	73·52	3·67	3·54		1·49	17·78	1·29	0·20	89·65	4·47	4·31		1·57	82·0	79·3	Contact with runner.	
25	Brockley (M.) ..	12·22	31·2	55·2	1·40	0·49	0·56	5865	72·20	5·01	20·63		0·56	1·60	0·56	Trace	73·39	5·09	20·96		0·57	98·4	86·4		
26	,, (A1) ..	2·95	7·3	84·6	5·05	0·83	0·08	7105	86·45	3·41	4·08		0·86	5·20	0·76	0·10	91·29	3·60	4·31		0·80	94·7	91·9	Natural cokes.	
27	,, (A2) ..	2·98	7·4	71·6	18·04	0·39	0·10	..	72·08	3·21	5·71		0·40	18·60	0·40	Trace	88·55	3·94	7·01		0·49	81·4	79·0		
28	,, (A3) ..	2·85	26·0	46·5	24·58	0·66	0·56	..	60·76	4·17	9·09		0·68	25·30	0·65	0·03	81·35	5·58	12·19		0·87	74·7	72·5		
29	Acheron ..	6·26	7·3	74·9	11·50	0·68	0·09	6825	77·87	3·01	6·13		0·73	12·26	0·60	0·13	88·90	3·42	7·00		0·68	87·6	82·1		

* Probably of same nature originally. Show progressive alteration. Order from dyke: A1, A2, A3, M.

CONCLUSION.

A review of the working hypothesis put forward to account for the formation of coals, and of the different methods hitherto proposed for their classification, leads to two general conclusions: (1) Future classification schemes will be based chiefly upon the results of chemical analysis, because those results are capable of exact quantitative expression; (2) all such classifications must be arbitrary, since no natural lines for division of coals into classes appear to exist.

Evidently the ideal basis of classification will not only satisfactorily arrange the coals in groups, but will also be successful in placing the members of each group in order of merit. Several of the factors that have been employed satisfy the first condition—they are able to separate into groups—but all fail when asked to put the coals of those groups in their proper order. One factor may be lucky enough to succeed fairly with one group; another with another group; but no one of them is adequate to the task of ranking the whole family of coals. The ideal basis of classification is still to be found.

Is there any chance of our finding it? It would be very foolish to answer such a question with a plain "Yes" or "No." It may be found; but there seems every probability that the time of its discovery will long be delayed. It certainly will not be found until we know more of the true nature of the coals to be classified; and then it may be no longer necessary to classify them. The present classification of coals has been aptly compared to the older classification of the rays of the solar spectrum—the crude but simple division of innumerable colours into violet, indigo, blue, green, yellow, orange, and red. Our so-called coal-groups are in the same position as our so-called colour-groups, and "no single division has any greater value than one of the arbitrary divisions of the rays of the spectrum designated by the name of a special colour." Yet colour-groups are necessary to the world of art, and coal-groups to the world at large. Our classifications, crude though they be, serve a useful purpose, and so long as we, for our part, remember to use them rightly—as aids to our imperfect knowledge—so long will they continue to render us service.

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ERRATUM.—Page 163, line 3, *for* Gruner *read* Grüner.

IRON STARVATION ON THE PATETERE PLATEAU.

By B. C. ASTON, F.I.C., F.N.Z.Inst.

AT the intersection of the 176th E. meridian and the 38th S. parallel occurs a large area of country known as the Patetere Plateau—an area of acidic volcanic rock elevated considerably above the surrounding land, and which supports on its coarse light soils a dense forest growth. This remarkable area has been examined in the vicinity of Mamaku, the largest settlement, whence sawmill tramways radiate out in all directions, rendering the examination of a heavily forested country easy. The railway-line to Rotorua passes over this plateau, and on both tramways and railways are numerous cuttings which enable one to compare the relation of the soil, subsoil, and rock in various parts of the district. In every section thus exposed there are three constant features: (1) The coarse pumice soil and subsoil is from 4 ft. to 5 ft. in thickness; (2) this deposit, named by Thomas "the Rotorua shower" (*Report on the Eruption of Tarawera and Rotomahana*, Wellington, 1888, p. 19) follows the contour of the country rock, and is therefore undoubtedly air-borne; (3) this deposit rests directly on the unweathered rhyolitic rock, there being no clay soil or organic matter between them. This rhyolitic rock the writer considers a lava-flow, on which the "Rotorua pumice-shower" fell before the lava had time to weather down into a soil sufficiently friable to support a vigorously growing vegetation. The quality of the lava at the junction of the pumice is just as hard and impenetrable as it is some feet below this old surface.

The present surface soil is derived from the air-borne pumice, which has become mixed with the remains of organic matter from the decay of the previous vegetation and the tawa-rimu forest which is now the plant covering of this unique area. The pumice does not completely form the soil of the tawa-rimu forest. Here and there are hillocks through which project outcrops of the country rock, with perpendicular sides at the summit. These have doubtless shed some detritus on to the pumice soil in the vicinity and possibly altered it for the better. The height of these pillars of rhyolite above the average level is about 40 ft., but near the Mamaku Railway-station is one which towers about 60 ft. high above the railway-line. There are hundreds of these pillar-capped hills in the district, and their presence gives a characteristic and pleasing variety to the landscape, which otherwise would be extremely monotonous.

The forest of this type of Makamu land is composed of tawa-rimu (*Beilschmiedia tawa* and *Dacrydium cupressinum*), about 75 per cent. of the millable timber being tawa and 25 per cent. rimu. To the north of the main road from Rotorua to Oxford (Tirau), which also cuts through the plateau parallel to the railway, but some miles north of it, the level of the country falls some 70 ft. and the soil becomes much heavier; the pumice is not obvious in the soil. The country rock comes more closely to the surface, and the vegetation changes in composition appreciably. The forest now is not dominated by the tawa and rimu, although these trees occur. It is the "birch," southern beech, or *Nothofagus* which is the dominant tree, there being two species present, *N. fusca* (red-birch) and *N. Menziesii* (silver-birch). The undergrowth also changes greatly

in composition, *Phyllocladus glauca* (toatoa) being a common shrub-tree of the new type of forest. Whence the soil which supports the "birch" forest is derived there may be some doubt. It is certainly much heavier, a given volume of the "birch" soil weighing about 10 per cent. more than the same volume of the State Farm (Mamaku) soil. It is not to be inferred that the change in vegetation absolutely synchronizes with the change in soil—the one type of forest merges gradually into the other; but the soil has been tested along a few miles of country, and the typical *Northofagus* forest has not been found off the particular type of soil specified in the area dealt with. It is, however, extremely probable that the tawa-rimu forest is invading the area occupied by the "birch," which type of vegetation the author regards as older than the tawa-rimu type.

The soil of the tawa-rimu forest may be designated a sandy silt, but the birch forest is not found off the sandy loam. The mechanical analyses may be set down as follows:—

	"Birch" or Southern Beech. (Per Cent.)	Tawa-Rimu. (Per Cent.)
Fine gravel	0·8	1·5
Coarse sand	15·6	29·5
Fine sand	26·8	22·1
Silt	23·8	16·7
Fine silt	11·1	7·3
Clay	3·4	2·2
Moisture	3·0	8·1
Loss on ignition	14·7	14·1

Chemical analysis shows that there is little difference between the two soils. The "birch" soils, however, contain about two and a half times the quantity of available iron that the tawa-rimu soils contain.

Turning to the economic utilization of the area, it may be said that as a timber-producing area the results are excellent, the rimu timber produced by the Mamaku mills being esteemed as good as any. When the sawmill has finished with a block of country, and the remainder of the unmillable timber and scrub is felled and burnt, and the area surface-sown with grass and clover seed in the usual manner, an excellent-looking growth of pasture is obtained. The exotic pasture-plants cocksfoot (*Dactylis glomerata*), red clover (*Trifolium pratense*), and white or Dutch clover (*T. repens*) cover the bare surface between the stumps which the fire has left, and there is no obvious evidence that the resulting sward is not everything that it should be. Experienced farmers, indeed, unacquainted with the country, are quite ready to venture their capital on the strength of appearances, so deceptive are these. The grass and the clovers especially thrive amazingly, and for the first few months mature stock also thrive, and also, under certain conditions, fatten.

Then disillusion begins, for the stock cease to thrive; although the feed remains plentiful, all ruminants lose condition, and eventually, if not removed to what is known to be healthy country, they die apparently of starvation —the prominent symptom (if it may be called such) being a progressive anaemia and increasing emaciation, the animal wasting away to a mere skeleton.

Post mortem examinations of animals which have died do not throw any light on the primary cause of the wasting. Many skilled veterinarians have

examined animals at all stages of the sickness, known in the district as "the skinnies," "bush sickness," or "bush disease." The result of their examinations may be consulted in the Department of Agriculture Annual Reports since 1896, and in the Department's *Journal* since 1910 (there is a collective index to this). It is not the writer's intention to deal with the pathological aspect, but it will be sufficient to say that the net result of much veterinary investigation, to which the trouble was naturally first submitted, was to refer the matter to the chemist as appropriately a matter for chemical research (see Reid, 1923, *The Diseases of Farm Animals in New Zealand*, p. 481). The matter was first brought under the writer's notice in 1903, and resulted in blood of affected and healthy animals being analysed fully. Subsequently, grasses and fodder plants, soils, waters, and anything which would bear on the matter were investigated. Visits were paid to the affected country, samples were personally collected; ultimately areas were leased or bought, and experiments were conducted on a fairly extensive scale. Up till the date of the purchase of a farm in 1912 there were few facilities for continuous experimentation in the field. At this time the writer, as the result of analyses, had advanced the hypothesis that iron starvation was the cause of the sickness (*N.Z. Journal of Agriculture*, August, 1912, p. 124). The purchase of the farm rendered it possible to test every idea which could be entertained—and these were many—of a remedy. Gradually the results of experiments began to point in one direction, and one which supported the writer's iron-starvation hypothesis. The war in 1914, and the subsequent retrenchment, undoubtedly retarded the work which had been begun on the farm so energetically in 1912. The work of the last few years has been recorded in the *N.Z. Journal of Agriculture* by the writer in the April–August, 1924, numbers. It will suffice to say that analysis of materials has been continued. Pot experiments have been made with soil from the Mamaku Farm, and the resulting clovers and grasses analysed. Feeding experiments with various medicinal compounds and licks have been exhaustively carried out at the farm. Various licks have been made up, and tested on cows and their offspring. The result is that the iron-deficiency hypothesis has been proved, and is now elevated to the dignity of a theory. The rhyolitic pumice, naturally a rock containing a low percentage of iron, had probably already been leached, and lost thereby more iron, before being redistributed in coarse gravelly and sandy particles—according to Thomas, about one thousand years ago, or some period of that magnitude. It was deposited from air, and gradually subsided, the loose soil probably first growing lichen, moss, *Raoulia* patches, fern and tutu (*Coriaria*), tussock, wineberry (*Aristotelia racemosa*), and other shrubs, *Leptospermum* (manuka)—an excellent nurse-crop for rimu forest, as may be seen at Hongi's Track, Lake Rotoma—and, finally, tawa-rimu forest. This succession on the material erupted in 1886 can be now seen in active progress on the slopes of Tarawera (see Aston, *Transactions N.Z. Institute*, vol. 18, p. 304, 1915, and *Journal of Ecology*, March, 1916). The first tree forest to succeed on this abnormal Mamaku soil is the one which is now in its maturity. There probably is no tree in the tawa-rimu portion of the forest over one thousand years of age, but those in the birch area may be older. The amount of humus produced by the first is the one saving factor in the successful growth of pasture, another being the high altitude (1,760 ft. above sea-level) and the resultant moist, cool climate and heavy rainfall. The soils of the "birch" area are, on the other hand, not derived from pumice of the Rotorua shower, and contain a greater proportion of

fine particles and a smaller proportion of coarse particles than the tawa-rimu soils. The "birch" forest is obviously much older, and appears to be dying out. The economic possibility of these "birch" soils has not been scientifically tested, but one would expect them to be less subject to "bush sickness," if not altogether immune, owing to their finer texture and wetter nature. Should this prove to be the case, these forest soils may, when the sawmills have taken their toll of the timber, and they have been burnt and grassed, provide suitable change-paddocks for the settlers on the tawa-rimu soils.

A summary of the results of the investigations of these abnormal soils may fittingly conclude this short paper. Mamaku pumice soil, tested by the Dyer method, contains a very small amount of available iron (0·03 to 0·07 per cent.) compared with other pumice soils which have been weathered by water and mixed with organic matter, and on which sick animals recover if grazed thereon (0·07 to 0·1 per cent.), while on non-pumice soils the iron may rise to 0·3 per cent. The ash of pasture-plants grown on Mamaku pumice soils is similarly low in iron (0·05 per cent.) compared with that of the same species of plant grown elsewhere. The green pasture is estimated to contain only 0·0025 per cent. of iron, whereas Hall (*The Feeding of Crops and Stock*, p. 4, 1911) assigns a value almost three times as great (0·007 per cent.) to the iron content of normal meadow-grass. The ash of pasture-plants in the spring and early summer is much lower in iron than the ash of those same plants later in the year, and it is in the early summer that cattle are most liable to suffer from the sickness.

Finally, although many substances—superphosphate, &c.—may alleviate the onset of the symptoms, there is only one substance which will cure an animal when considerably affected with bush sickness, and that is iron in one of its organic salts—the double citrate of iron and ammonia (the ferri ammon. cit. of the druggist) has been found the most effective remedy. A 6-per-cent. solution given in 2 oz. doses twice a day will effect a recovery in every case where the sickness is in its early stages. It is expected that the solution is more effective when made slightly acid than when neutral. It may be given in pressed-brick form, in which case 8 lb. of raw sugar to 4 oz. of the ferri ammon. cit. scales may be given to cattle, which greedily consume it in this form. It has always been a stumbling-block to stockmen that horses can thrive and live for years on the same pasture that a cow will starve on and die in nine months; but this very fact is one of the proofs of the iron-starvation theory, for it is known that the proportion of iron in the milk of the mare is only half that in the milk of the cow, and the amounts of mineral foods required by animals are best determined by a study of the milk-ash composition of each species. The iron requirement of the horse is therefore much less than that of the cow, and very much less than that of the sheep. It is in just this order that the animals are affected on virgin pasture. Sheep cannot be kept healthy longer than six months, and cattle not longer than nine to twelve months, whereas horses may be kept healthy for twenty years on the same pasture. Imported concentrated foods such as bran, meals, molasses, &c., enable stock to be kept healthy on the pasture upon which otherwise they would go sick. The foods contain more iron than the same bulk of pasture; and one experiment of feeding with wilted pasture to sheep was successful in keeping the animals healthy over a period of some months after their control companions had sickened and died.

It must not be lost sight of that it is probably the texture, and consequently the water-holding power, of the soil which is the initial

cause of the sickness. Other soils may contain as little iron, but the highly aerated condition existing in the porous pumice soil may prevent the iron from going into solution in the soil-water, and thus the plant may be unable to absorb sufficient to enable it to nourish the animal. It is significant that applications of quicklime or carbonate of lime to the pasture makes the animals pastured upon it sicken more quickly than if they were grazing on the untreated pasture. The iron is perhaps inhibited to a greater extent from entering into solution by the lime. It is noteworthy that the "coastal disease" which competent veterinarians consider is identical with "bush sickness" occurs on dune sandy land on King Island, Tasmania, which contains 40 per cent. of carbonate of lime. In Nairobi, British East Africa, a disease similar to bush sickness develops on a *grey* volcanic-ash soil in cattle, which recover if removed to *red* volcanic soil.

The subject is of immense national importance to the Dominion, as it is estimated that over a million acres are affected.

FURTHER NOTES ON THE CHEMISTRY OF THE NEW ZEALAND FLORA.

By ROY GARDNER, M.Sc., A.I.C.

SINCE the former notes on this subject (this *Journal*, vol. 6, 1923, pp. 147–51) were written, several papers have appeared, and my attention has been drawn to a number of additional references. As communications from several sources have shown that the attempt to synopsize the subject and to compile a bibliography was appreciated, these additional notes are now given.

ALKALOIDS.

Several alkaloids, of which the principal is named pukateine, and has the formula $C_{17}H_{17}NO_3$, have been found by Aston in the bark of the pukatea (*Laurelia novae-zelandiae*). Pukateine acetate is soluble in chloroform. The physiological action of the alkaloid has been investigated by Dr. Malcolm.

FIXED OILS.

That of *Passiflora tetrandra* has been investigated by Aston, who remarks that it is worth further investigation.

TANNINS.

A series of papers by Aston on "Indigenous Tans and Vegetable Dyestuffs" (see references) gives an excellent summary, with much new work.

With regard to koromiko, it appears plain both from the literature and from experience that neither the tincture nor the infusion carries the medicinal virtue of the leaves. Opinion on the value of the decoction is divided, and it is probable that variation in the exact method of preparation is to some extent the trouble. It is suggested that the powdered air-dried leaves may be worth examination from the point of view of their potency—at least, in veterinary medicine. Attempts are being made to investigate more closely the chemical nature of the active substances.

ESSENTIAL OILS.

The oil of *Dacrydium cupressinum* has been extracted in the Otago University laboratories, and found to contain solid substances, which are being investigated by Mr. F. H. McDowall.

MISCELLANEOUS.

Amongst others, the following are mentioned by Aston as poisonous or suspected: *Pimelea* bark, *Ranunculus rivularis* (waoriki), *Myoporum laetum* (ngaio), *Brachyglottis rangiora*, *Dianella* berries, the young growth of the common bracken-fern, *Melicytus ramiflorus*, kowhai-seeds, *Hydrocotyle asiatica*. Most of these should be worth further investigation.

The subjoined bibliography contains references to work mentioned in the above notes, as well as to a number of papers which were either unpublished or unknown to me when the previous notes were written.

My thanks are due to a number of correspondents for interesting information and suggestions, and particularly to Mr. B. C. Aston, Chief Chemist to the Department of Agriculture, for a great deal of information and for a set of the publications of the Department containing accounts of chemical work on the flora.

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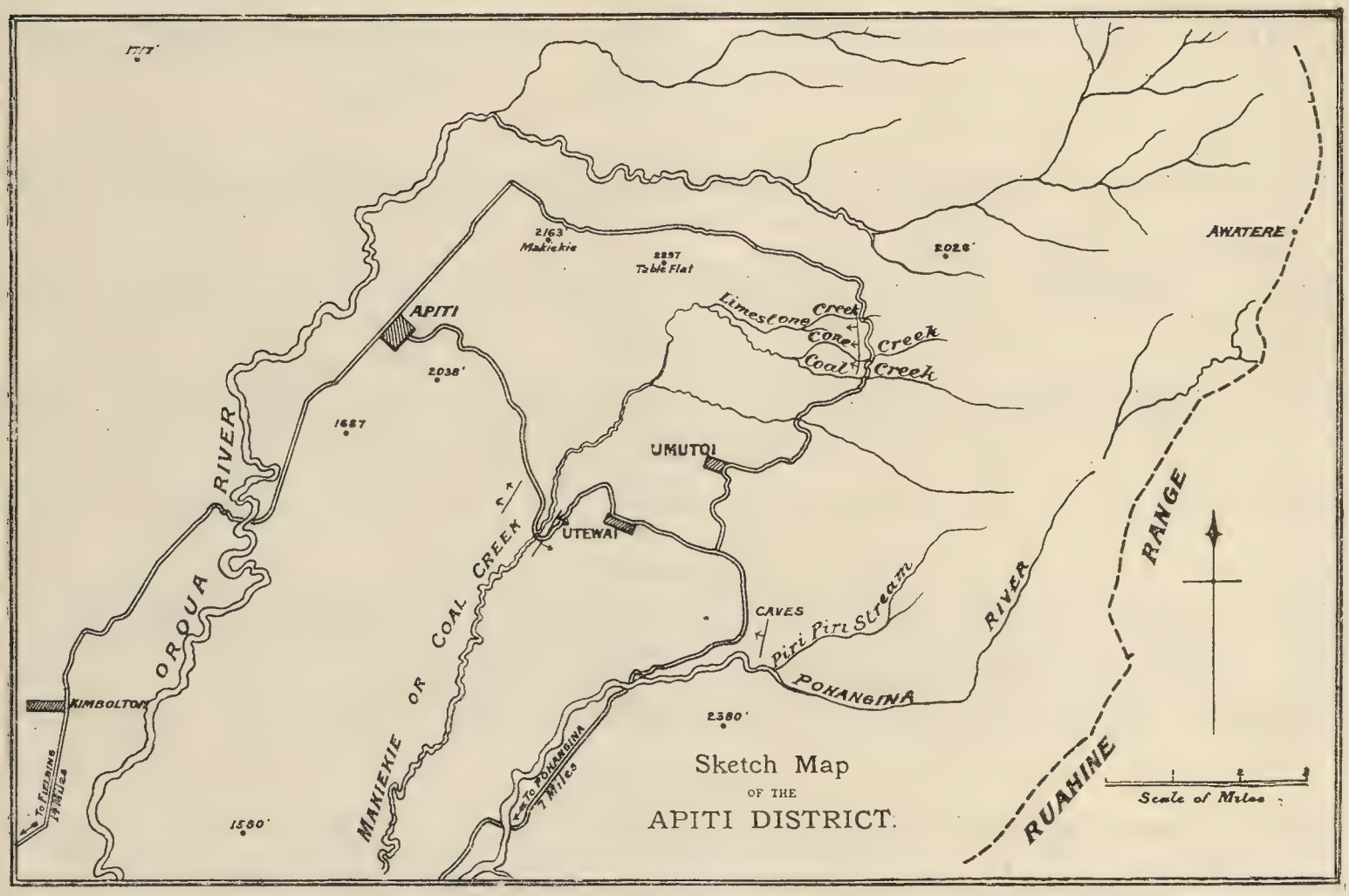
NOTES ON THE GEOLOGY OF THE DISTRICT NEAR APITI, POHANGINA COUNTY.

By R. SPEIGHT, F.G.S. Curator, Canterbury Museum, and L. J. WILD, F.G.S., Director, Agricultural High School, Feilding.

IN the bulletin on the limestones of New Zealand (No. 22, 1919) there is a reference to the want of knowledge of the geology of the Kiwitea and Pohangina Counties, and this has prompted the writers to furnish a short account of the results of observations made during a recent visit to the locality. The account is necessarily incomplete, but it may serve to direct attention to an interesting district. The area covered is that around Apiti—a little township lying about thirty miles north-east of Feilding—and specially that lying between the Oroua and Pohangina Rivers as they debouch on to the Wanganui coastal plain from the foothills of the Ruahine Range.



Sketch Map OF THE APITI DISTRICT.

This plain has a general elevation in this region of from 1,700 ft. to 2,000 ft., but it has been dissected by the rivers and their tributaries to such an extent that only remnants of comparatively small extent of the original highest surface survive; but in cutting down to their present levels the rivers have in many cases formed very wide terraces, the surfaces of which are as level as the original plain and simulate its features very closely. In general there appear to be three well-marked terraces, with a total height in the vicinity of Apiti of over 700 ft., and the rivers are at present flowing in meanders entrenched on the floor of the last terrace, and are in process of removing the spurs which run down between adjacent loops. The terraces are probably to be attributed to successional

uplift of the land; and, as they are higher in the interior than near the coast, the elevation was in all probability differential in amount and more pronounced in the interior, there being no obvious cause except differential uplift to account satisfactorily for the river-valleys being deeper in their upper reaches.

It will be noticed, too, that the courses of the rivers such as the Oroua, Pohangina, and their tributaries are subparallel in direction. This may result from the fact that they were consequent streams flowing in their most direct line to the sea on the land surface as it emerged at the close of the Tertiary era or at the beginning of the Quaternary; but there is some evidence of the influence of structure, for the Oroua in the vicinity of Apiti occupies the axis of a very open gentle anticline, while Coal Creek, a tributary of the Pohangina, occupies the axis of another parallel but very acute anticline, and the Pohangina flows along the strike of the beds tilted against the greywackes of the Ruahines. The agreement of the positions of the stream-valleys with the axis of the anticlines may be only a coincidence and have no special significance, but it is a coincidence that should be noted.

As the beds of which the country is composed have little resistant power, the dissection of the ridges between adjacent valleys is proceeding apace, and streams in all stages of diversion may be observed. Apiti itself lies on the old flood-plain of the Oroua River, which has deserted its former course and flows in a direction more to the west, and has incised its bed some 600 ft. below the old channel, a result probably arrived at by a supparallel tributary capturing the main stream higher up in its course—a case of auto-capture. The floors of these old river-beds are usually distinguished by a stony soil, entirely different from that which characterizes the higher land levels and the steep slopes of the terraces facing the rivers, where the soil is usually clayey or sandy, since it has been formed from slip and slump material from the Tertiary clays and sands.

The rocks of the area belong to the Wanganui system. They lie unconformably on the greywackes of the Ruahine Range, and wherever observed the relations appear to be a normal unconformity and not a fault contact. At no place was the actual junction between the two series observed, owing to the covering of bush or of surface accumulations, but the clearest sections were those in Coal Creek and in Cone Creek, a tributary lying immediately to the west of it. The sequence here observed was as follows:—

(1.) Greywacke, of the usual kind.
(2.) Quartz sands, grey in colour.
(3.) Marls.
(4.) Sands, containing shell-fragments in their upper parts.
(5.) Pebbly calareous sandstone conglomerate—the lower 15 ft. containing few pebbles, and being really a calcareous sandstone; the upper part, about 40 ft. thick, containing more pebbles, and approaching in the concluding stages a conglomerate with shell-fragments.

These beds strike N. 5° W., and dip westerly about 10°, the total thickness down to the greywackes being about 500 ft.

This layer of calcareous conglomerate is a possible source of crushed limestone for use in agriculture locally. Although somewhat remote, it is in a moderately favourable situation for working; and, providing the calcium-carbonate content is satisfactory, it could be used in the

neighbourhood of Apiti, which is very unfavourably situated for procuring supplies from other sources.

Partial analyses of the beds numbered (5) above are here given—for these our thanks are due to Mr. G. V. Wild :—

	5 (*a*).	5 (*b*).
Sand and insoluble	17·30	29·24
Iron and aluminium oxides	2·02	2·36
Calcium carbonate	79·20	67·00
Moisture and undetermined	1·48	1·4
	100·00	100·00

5 (*a*), composite sample from lower 15 ft.; 5 (*b*), composite sample from upper 40 ft.

In Limestone Creek, about half a mile west of Cone Creek, there is a similar calcareous conglomerate. The bed is exposed in a deep, narrow gorge over which the road passes by taking advantage of what is practically a natural bridge. The gorge portion of the stream is about 7 chains in length, and is over 50 ft. deep, and the whole course is very deeply incised with precipitous banks. The rock exposed on the sides of the gorge is almost completely covered with a layer of crystallized limestone, which is stalactitic in places, so that it was found impossible with the means at our disposal to determine the nature of the bed at different levels, but it is apparently similar in nature to the bed just described, and consists of sandy gravels with a varying admixture of shelly and other calcareous material. Owing to the surface of the country between Cone and Limestone Creeks being completely masked by surface accumulations, it was not possible to determine definitely whether this bed is a continuation of the one occurring farther east, but from a general consideration of the circumstances, including the possibility of faulting, it seems reasonable to consider it as existing at a lower horizon, and both beds are apparently merely local developments of a more calcareous layer in a calcareous sandy bed laid down on a varying sea-bottom.

Succeeding the limestone facies at the bridge are the following: Sands with fragments of shells, 4 (?) ft.; sands, 15 ft.; gravels, 4 ft.; blue sandy clays, 10 ft.; gravel bed, 1½ ft.; grey sands, 30 ft: all with the same dip and strike—viz., strike, N. 5° W.; dip, westerly 10°.

This is apparently the locality of origin of the crystallized limestone with 97·5 per cent. of $CaCO_3$ recorded by Aston (*N.Z. Jour. Agric.*, p. 99), the high percentage being attributable to stalactitic material or to mere surface incrustation, and in no way representing the true carbonate content of the rock. Such analyses, unless the whole circumstances are given, are very misleading, and worse than useless, especially with people who from want of experience are not able to interpret them correctly.

The location of this deposit at the bottom of a gorge-like valley, and its uncertain bulk-composition, make it unworthy of serious consideration as a source of supply of calcium carbonate for agricultural purposes, although detailed investigation may disclose a layer of rock with moderately satisfactory calcareous content.

A somewhat similar bed occurs about four miles to the south-east, on the Piripiri Block of the Umutoi district, in the basin of the Pohangina. In this case there is an exposure of a sandy or gravelly bed with shells

along a ridge for a distance of half a mile approximately, the northern end being a spot of some scenic interest owing to a deep and picturesque gorge with caves cut in the calcareous beds. At this end of the ridge the bed is 50 ft. thick, with a north-easterly strike, and a south-westerly dip amounting to 20°. Where sampled the beds were a fine-grained calcareous sandy conglomerate with shell-fragments. They overlie a thickness of over 100 ft. of blue sandy clays.

Near the south-eastern end of the ridge the strike is the same, but the dip steepens to about 45°. The bottom 8 ft. of the bed contains numerous subangular pebbles of greywacke in a sandy calcareous matrix with shell-fragments, the succeeding layer being sandy with only occasional pebbles, and yielding—sand and insoluble, 27 per cent.; calcium carbonate, 72 per cent. Under the limestone is a grey sandy marl much bored with worm-tubes near its upper surface, recalling the contact of the Weka Pass and Amuri limestone in the North Canterbury area; while under this is a grey sandy clay of a total thickness of about 250 ft., the whole resting on greywacke, exposed in the bed of the Pohangina and its tributaries as they issue from the foothills of the Ruahines.

On following down the Pohangina as far as the bridge the strike becomes more northerly, and the dip as low as 10°. The beds consist of sandy calcareous clays with occasional shell-fragments interstratified with pebbly layers containing shells, these layers being very variable in thickness.

The horizon of the calcareous beds has not been definitely determined, since it was not convenient at the time of our visit to make a collection of the fossils. Species of the following genera were recognized: *Fulguraria*, *Crepidula*, *Calyptraea*, *Ancilla*, *Turritella*, *Ethalia*, *Glycymeris*, *Pecten*, *Lima*, *Ostraea*, *Balanus*, &c. The limestone localities at Cone Creek and in the Pohangina would no doubt repay collecting, as the fossils are fairly well preserved and the number of individuals is large.

The contact of these beds with the greywackes was carefully considered in order to see what evidence there was of the extension of the faulting recorded by Park farther south, near the Manawatu Gorge. Wherever we could see the relations between the two sets of beds it was one of a normal unconformity. There was, however, a striking physiographic feature which has an important bearing on the question—viz., the faceting of the ends of the greywacke spurs of the Ruahine Range where they terminated, which might suggest a fault-line. The regularity of this was remarkable, recalling the faceting seen in glaciated valleys where the feature is typically developed. At first sight this form suggested faulting, but it was noticed that the angle of inclination of the overlying Tertiaries was in agreement with the slope of the facets. Had the beds been in fairly close proximity one might have regarded them as having been upturned along a fault-plane, but the fact that they are at least half a mile away from this line rather militates against that explanation. It appears more probable that these facets are remnants of the surface on which the Tertiaries were laid down, which have escaped destruction or serious modification by erosive agencies—that they are, in fact, "stripped surfaces" as named by Thomson. The beds which once overlay them, owing to their weakness and incapacity to resist active erosion, have been removed very rapidly along the line of junction, and the more resistant greywacke surface has escaped with but little modification. The tilting of the later beds has been caused by the movements that raised the Ruahines, which affected the beds, once perhaps covering them or resting against their flanks. The former have completely gone, and the latter have

gone except at the lower levels on the flanks of the chain, where they dip under the Wanganui coastal plain. The deformation produced by the folding is probably more marked to the south, and the fold grades into a fault, with more and more definite throw, as followed for some distance along the western base of the Ruahines, in accordance with the observations made by Park (*Rep. Geol. Explor.*, 1887, p. 34). The Ruahines thus resemble a number of other ranges in New Zealand in being associated with a fold of the covering beds, grading into a fault when traced in one direction or the other, sometimes in both, the remnants of the former cover existing as a rule only on the flanks, but occasionally in the form of small outliers on the higher levels of the range, where they have been protected in some way from the active erosion which has removed the cover elsewhere. Such remnants do not apparently exist in the Ruahines. This deformation of the surface is evidently most pronounced along the margin of the range, since the effect peters out as the beds are followed towards the west and south-west. In the neighbourhood of the Oroua the anticlines are very open, with the limbs very gently inclined; but between this line and that of the Pohangina there is a very acute anticline running up the line of Coal Creek. Park records (*loc. cit.*, 35) that the beds are very highly inclined in the lower part of Coal Creek, but he evidently did not recognize their anticlinal arrangement. This is quite clear in the vicinity of the point where the road from Apiti to Utewai crosses the stream. Near the bridge the beds consist of sands, sandy clays with occasional pumice-sands, especially at higher horizons, interstratified with massive gravel-beds with layers of shale and impure lignite at various levels. The lowest beds exposed in the core of the anticline are brownish-grey sands. The strike of the beds is north-east and south-west, and the dip south-east at an angle of 30°. As the road is followed towards Apiti the dip is reversed and becomes very gentle, and this anticline is succeeded by a very gentle one along the line of the Oroua.

Unless an unconformity exists in the Tertiary sequence, the section in Coal Creek should represent beds very near its base, and be equivalent to the beds underlying the limestones at Piripiri and Cone Creek; but no limestones were seen on the flanks of the anticline at all comparable with these two occurrences. It is possible that the greywackes are at but shallow depth under the bed of the stream, and that they would have been exposed if the stream had cut a little deeper.

Farther up Coal Creek the beds exposed consist of blue sandy clays dipping west, and a similar dip occurs on Table Flat, between Coal Creek and the Oroua, an arrangement which is continued across the Oroua just below the point where it issues from the greywacke gorge it has formed in the foothills of the Ruahines.

In the Oroua west of Apiti the characteristic beds appear to be greenish sands and sandy clays, with an occasional hard band composed of calcareous sands with shells. Some of these bands should yield a fair harvest of fossils; and one especially to be noticed is on Mr. Bennet's farm, about a mile and a half north of Apiti, where the following fossils, kindly identified by Dr. Marwick, were collected: *Calyptraea inflata* (Hutton), *C. tenuis* (Gray), *Crepidula monoxyla* (Lesson), *Glycymeris modesta* (Angas), *G. shrimptoni* (Marwick), *Mytilicardia trigonopsis* (Hutton), *Trophon ambiguus* (Phil.), *Xymene drewi* (Hutton). In higher level horizons pumice-sands become a dominant member of the series, as can be seen clearly near the point where the road from Kimbolton to Apiti crosses the Oroua.

THE DIVINING-ROD.

By M. ONGLEY, M.A., B.Sc.

As a large sum of money is spent every year in New Zealand in searching for underground springs, coal-seams, and other mineral deposits located by diviners; as Parliament has been several times urged by members, farmers' unions, &c., to participate in developing these alleged valuable discoveries; and as different diviners in New Zealand claim to have found underground springs of water, subterranean streams and pools of oil, coalfields, lodes of gold, silver, &c., and to know the quality, extent, and depth of the deposits, to have found and counteracted the cause of goitre, tuberculosis, and cancer, &c., by the divining-rod or by related means—it may be useful to give a short account of the cult of divining. It may appear impertinent to offer such an account, especially to men of strong conviction; but as some have been persuaded by specious argument or apparently successful experiment, and have had no chance to read about divining, this contribution may not be out of place. It is for the most part extracted from *The Divining-rod: a History of Water-witching*, issued as Water-supply Paper 416 by the United States Geological Survey in 1917 as a reply to numerous inquiries from all parts of that country.

The origin of the use of the rod is lost in antiquity; but rods or wands were in use among ancient peoples for forecasting events, searching for lost objects, and in occult practices generally. The Scythians, Persians, and Medes used them. Heredotus records that the Scythians detected perjurers by means of rods. The Greeks practised this art, and the reputed magic power of the rods of Minerva, Circe, and Mercury is well known.

Whatever the early references to rods and wands signify, no conclusive evidence has been found of the use of the divining-rod as it is now known earlier than the sixteenth century; and W. F. Barrett, F.R.S., Professor of Physics in the Royal College of Science for Ireland, who undertook a laborious investigation of divining, is practically certain that the birthplace of the modern divining-rod was in the mining districts of Germany—probably in the Harz Mountains, where the most approved mining processes were first devised. The first published description of it known is contained in Agricola's *De re Metallica*, published in 1556. As the ideas there expressed are strikingly similar to the "new discoveries" made to-day, the following translated extract from that work may be useful:—

> There are many great contentions between miners concerning the forked twig, for some say that it is of the greatest use in discovering veins, and others deny it. Some of those who manipulate and use the twig first cut a fork from a hazel-bush with a knife, for this bush they consider more efficacious than any other for revealing veins, especially if the hazel-bush grows above a vein. Others use a different kind of twig for each metal when they are seeking to discover the veins, for they employ hazel-twigs for veins of silver, ash-twigs for copper, pitch-pine for lead and especially tin, and rods made of iron and steel for gold. All alike grasp the forks of the twig with their hands, clenching their fists, it being necessary that the clenched fingers should be held toward the sky in order that the twig should be raised at that end where the

two branches meet. Then they wander hither and thither at random through mountainous regions. It is said that the moment they place their feet on a vein the twig immediately turns and twists, and so by its action discloses the vein; when they move their feet again and go away from that spot the twig becomes once more immobile.

The truth is, they assert, the movement of the twig is caused by the power of the veins, and sometimes this is so great that the branches of trees growing near a vein are deflected toward it. On the other hand, whose who say that the twig is of no use to good and serious men also deny that the motion is due to the power of the veins, because the twig will not move for everybody, but only for those who employ incantations and craft . . .

Since this matter remains in dispute and causes much dissension amongst miners, I consider it ought to be examined on its own merits. The wizards who also make use of rings, mirrors, and crystals seek for veins with a divining-rod shaped like a fork; but its shape makes no difference in the matter—it might be straight or of some other form—for it is not the form of the twig that matters, but the wizard's incantations, which it would not become me to repeat, neither do I wish to do so . . .

It is a conspicuous fact that these cunning manipulators do not use a straight twig, but a forked one, cut from a hazel-bush or from some other wood equally flexible, so that if it be held in the hands as they are accustomed to hold it, it turns in a circle for any man wherever he stands. Nor is it strange that the twig does not turn when held by the inexperienced, because they either grasp the forks of the twig too tightly or hold them too loosely. Nevertheless these things give rise to the faith among common miners that veins are discovered by the use of twigs, because whilst using these they do accidentally discover some; but it more often happens that they lose their labour, and although they might discover a vein they become none the less exhausted in digging useless trenches than do the miners who prospect in an unfortunate locality. Therefore a miner, since we think he ought to be a good and serious man, should not make use of an enchanted twig, because if he is prudent and skilled in the natural signs he understands that a forked stick is of no use to him, for, as I have said before, there are the natural indications of the veins which he can see for himself without the help of twigs . . .

This account of divining published in 1556, answers many of the questions raised periodically up to the present time, and is in many respects quite modern.

From Germany the twig was taken into England by the German miners who were imported in Elizabeth's reign to develop the mines of Cornwall; and before the end of the seventeenth century the cult had spread over Europe, not, however, without much opposition. Its champions, among whom were some of the most learned men of the time, explained its operation as due to "sympathy" or "attraction and repulsion," "like gravity and magnetism." Some adversaries, on the other hand, condemned its use as superstitious and vain practice; and others maintained that its movements were influenced by demons. In Cornwall the belief was common among the miners, and still persists as a tradition, that the divining-rod was guided to the ore by the pixies, the fairy custodians of the mineral treasures of the earth.

From being used in locating minerals the rod, about 1650 in southern Europe, and near the end of the eighteenth century in England, began to be used as it is generally used to-day, to divine water. This power of the rod was first claimed for it by Baron and Baroness Beausoleil. The baron devoted himself to mineralogy, and became undoubtedly one of the foremost mine engineers of his time. He visited and studied the mines of Germany, Hungary, Bohemia, Tyrol, Silesia, Moravia, Poland, Sweden, Italy, Spain, Scotland, England, and France. He was in control of the mines of Hungary, Tyrol, Trent, Bavaria, Neuberg, Cleves, and the Papal States; and discovered one hundred and fifty mines in France, and also some medicinal springs. The baron was the first to claim to be able to find water with a rod. This new application of the rod no doubt tended

to popularize it, for, previously, it had been of interest chiefly to miners, and outside of mining districts it was probably known only in a vague sort of way; but as a "water-finder" it became more generally known, and its successes outnumbered its failures, as is maintained by Barrett's letter to the *Times* on the 21st January, 1905, quoted in the *Encyclopaedia Britannica* as follows: "Making a liberal allowance for failures of which I have not heard, I have no hesitation in saying that where fissure water exists and the discovery of underground water sufficient for domestic supply is a matter of the utmost difficulty, the chances of success with a good dowser far exceed mere lucky hits, or the success obtained by the most skilful observer even with full knowledge of the local geology."

Wherever it went the rod caused great controversy. Father Kircher, about 1670, suspended rods on pivots and showed they were not affected by the proximity of metals or minerals. Father Schott, in 1659, denounced it as controlled by the devil, but later expressed the belief that its movements were probably not caused by the devil, as "monks of great piety have used it with really marvellous success, and affirm positively that the movement is entirely natural, and that it does not at all proceed from dexterity or from the strength of imagination of him who uses it"; and he and Father Kircher advanced the theory that the movements of the rod are due to unconscious muscular action.

The diviners, disregarding all controversy, carried on their work, and in 1675 J. C. Frommann, a doctor of medicine, ridiculed those who explained the movements of the rod as a sleight-of-hand trick, and compared the mystery of the rod with the mystery of reproduction. In 1684 another doctor of medicine, G. B. Saint-Romain, explained the movements of the rod as due to emanations given off from minerals and underground streams.

Although many contended against the use of the rod, the diviners had a popular triumph in 1692, when criminals were tracked, identified, and apprehended through the agency of Jacques Aymar, a French peasant, who claimed to be able to trace criminals with his rods. The case excited intense widespread interest, and has been much discussed. Commenting on it in *Psychical Research*, W. F. Barrett wrote: "The other one, a hunchback, who was arrested, confessed the crime and was executed. . . . . Strangely enough, the depositions made at the trial showed that Aymar (the diviner) was correct in every detail, witnesses testifying to the flight and halting-places of the culprits in the very places Aymar had indicated. . . . . Aymar became notorious throughout Europe. He was, however, subsequently somewhat discredited owing to his failure in some "tests devised by the Prince de Condé."

The idea that the twig would point out criminals, and the related belief that the rod was under the influence of demons, died out about the beginning of the eighteenth century.

About 1780, when the early experiments in electricity were mystifying the people and when Galvani demonstrated that amputated legs of frogs could be made to twitch under electrical stimuli, the advocates of the divining-rod seized this as affording a scientific explanation of the movement of the divining-rod, and explained the puzzling dipping of the twig by the still less known electricity. This explanation became a popular craze with those who had the proverbially dangerous little knowledge, and several men claimed to be electrical hydroscopes, as several still do to-day in New Zealand and elsewhere.

After the operations of the "magic pendulum" had in 1812 been shown to be due to involuntary muscular action, and after Faraday had shown that the mysterious table-turning was likewise due to the same involuntary effort, Chevereul, a member of the committee appointed by the Academy of Science to investigate the divining-rod, concluded that the movement of the divining-rod was also due to involuntary muscular exertion. With the growth of psychology and the investigation of mental processes this explanation of involuntary muscular action has been demonstrated to be the efficient cause of the motions of the twig, so that, as Raymond has shown, there remains practically no grounds for believing in the power of the rod to discover moral qualities, locate landmarks, trace criminals or stolen property, or foretell the future. Raymond concluded: "In itself it [the rod] is nothing. Its claims to virtues derived from Deity, from Satan, from affinities and sympathies, from corpuscular effluvia, from electrical currents, from passive perturbatory qualities of organo-electric force, are hopelessly collapsed and discarded. A whole library of learned rubbish about it which remains to us furnishes jargon for charlatans, marvellous tales for fools, and amusement for antiquarians; otherwise it is only fit to constitute part of Mr. Caxton's *History of Human Error*. And the sphere of the divining-rod has shrunk with its authority. In one department after another it has been found useless. Even in the one application left to it with any show of reason it is nothing unless held in skilful hands, and whoever has the skill may dispense with the rod. It belongs with the 'magic pendulum' and 'planchette' among the toys of children. Or, if it be worthy the attention of scientific students, it is the students of psychology and biology, not of geology and hydroscopy and the science of ore deposits, who can profitably consider it."

Still, though the rod had been used by many quacks, so many wells have been successfully located by it that Barrett came to the conclusion already quoted, and Raymond, although writing the strong statement against the rod just quoted, wrote in the same article, "The case is somewhat different with the discovery of springs and (since they always have been and often still are the channels of springs) of ore deposits. Here we have much stronger and more abundant evidence in favour of the rod; and here, in my judgment, there is a residuum of scientific value, after making all necessary deductions for exaggeration, self-deception, and fraud. . . . Is it not probable that a single unconscious chill may be the physical result, to certain sensitive persons, of walking over a spring of water, or a belt of rock or soil kept by running water cooler than the adjacent rock or soil, or a spot of surface made by the same cause damper than the surrounding surface? That these causes exist is beyond doubt. Thermometrical measurements have not been made; but the way in which grass grows, and snow lies, and frost settles, and vapours rise over springs is due to the temperature and moisture of the ground in such places."

At the present day it is difficult for any one to weigh the evidence presented in the sensational cases of Aymar, Bleton, and others; but it is important for us to find out if any diviner to-day can find water, gold, coal, oil, or anything else. Several scientific tests have been made of diviners, and in these the diviners have failed hopelessly. Still they are employed to find water and other substances, and are sometimes successful. It has been asserted by Professor Barrett that the successes far exceed those "obtained by the most skilful observer even with full knowledge of the local geology." This conclusion of Barrett's was challenged by James Mansergh, who, in a

presidential address (6th November, 1900) claimed that many of the two hundred successful wells relied on as proof by Professor Barrett could be easily detected by surface indications. This is reported on in *Popular Fallacies* by A. S. E. Ackmermann (1923), in which pages 760–65 are devoted to showing that divining is nonsensical, and giving references to the tests made.

Seven diviners submitted to a test in Guildford, England, and failed miserably. Other diviners have been tested in Holland and Germany; and the result of the last German tests of three diviners, including one who had been certified to by the Internationaler Verein der Rutenganger (International Society of Diviners), as reported in the *Bulletin of the American Association of Petroleum Geologists* for July–August, 1923, show that none of these had any special ability to find water, potash, or coal under test conditions, and led to the following conclusion: "The results of the tests speak for themselves, and in conclusion Beyschlag makes the comment that if there were something to the wiggle-stick, its failure at times to register the presence of a substance might be explained, but that its brilliant registering of substances not present could not be."

As the same conclusion has been established by several series of tests, and the rod has been discredited by many scientific bodies, it is rather surprising to find that the practice is generally believed in throughout New Zealand, and that we have several diviners working in this country to-day. A little information about their activities has been gathered, and the following facts are presented in the hope that more information will be gathered and circulated. It is realized, however, that the only man able to give a full account of any diviner's work, including both successes and failures, is the diviner himself, and that, while a man who has been successful in this trial is eager to tell about it, one who has failed feels that he has been a fool and does not wish to advertise it. Still, the failures experienced are valuable as lessons to others, and should be recorded.

It is, then, more or less gratifying to know that the New Zealand diviners claim to be able to do as much as, if not more than, those of any other land. They claim to be able to find, and to have found, flowing subterranean streams of water or oil, coal, silver, gold, and some seventy minerals; to ascertain the depth at which the body lies, and to estimate its quality and quantity; to find and counteract the causes of goitre, rheumatism, cancer, tuberculosis, &c. They assert that they can do these things by divining, by radio-analysis, by magnetic attraction, by electricity, by bodily sensation (as a feeling of silver on one side of the body and gold on the other), by human magnetism, and by the more or less unknown processes that go under the name of "divining." They are employed by County and Town Councils, Hospital and Harbour Boards, Government Departments and Farmers' Unions, landholders, &c., and their fees range from voluntary donations to £5 5s. a day. When proof or evidence of their powers is sought, little is forthcoming. Members of the staff of the Geological Survey Department have been trying for years to get in touch with them and to ascertain statistically how their work succeeds, for an isolated success or failure may be misleading. For instance, suppose water be struck in a hole bored on a site located by the diviner, what is proved? Unless we know whether this is his only success in some fifty ventures, or his forty-ninth, we are not able to come to a conclusion. Where reliable figures have been supplied, as in New South Wales, we find (*Chem. Eng. & Min, Rev.*, vol. 13, No. 150, p. 193)

that, out of sixty-four sites located by diviners and bored, one in every three failed; whereas, of 120 located without the rod, only one in five failed. These figures indicate that the diviners have no special powers, and show how dangerous it would be to generalize on a single success. In New Zealand no one has been able to get such figures. Diviners claim for themselves 98½ per cent. successes in locating water and 100 per cent. successes in curing disease; but reliable reports available show that, of twenty sites located, fifteen were failures and five successful, while certain diviners have failed in numerous tests, and others decline to be tested.

In water-divining, as in all branches, we have rumours of many finds being made; but a diviner and a journalist often make no distinction between the alleged find that the diviner asserts is below and what is actually found. For instance, in August, 1919, the Wellington papers contained several references to important subterranean springs of water having been "found" by a diviner in Seatoun. Still, we cannot get information from the papers or the local bodies as to whether any water was ever struck in the sites recommended. In cases of water "located" by a diviner and bored for we have authentic accounts of fourteen failures and five successes. The successful wells are 22 ft., 25 ft., 12 ft., 55 ft. and 74 ft. deep. The diviner who located three of these was subjected, to forty tests and failed in thirty-five. Four of the successful wells are on alluvial plains, and the other is in a small alluvial drainage-channel. The other diviner's bore of which we have a reliable account was for coal, and was a failure. Among these failures single bores have cost £1,000.

This record is meagre, but is reliable and significant. It is desirable that additional reliable data be recorded. We know, for instance, from the newspapers that oil-diviners have "located" huge fields at New Plymouth, Eltham, Mercer, Pongaroa, and in Canterbury and Otago. If we can get reliable information as to what the diviners predicted and what was found we shall be glad to use it in forwarding this inquiry. Similarly, any other information on this subject is acceptable. The present state of our record accords with that established elsewhere, and indicates that in New Zealand there is not one diviner known who is worth consulting.

PRIMITIVE WINGLESS INSECTS.

PART I: THE SILVERFISH, BRISTLETAILS AND THEIR ALLIES (ORDER THYSANURA).

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THOUGH the great majority of insects possess wings, there are a large number of groups in which these organs are entirely absent. If we consider such well-known insects as the bed-bug or the weta, it does not take us long to come to the conclusion that their ancestors must have had wings, and that

they have been lost through atrophy, following on long disuse. Nearly all bugs have wings, even in those families most closely allied to the bed-bug; and nearly all long-horned grasshoppers have wings, even in groups closely allied to the wetas; so that there is ample evidence of a fairly recent descent from winged forms both in the case of the bed-bug and the weta.

When we consider certain parasitic wingless insects such as the fleas and lice, we are still able to come to the conclusion that they must have descended from winged ancestors, even though at the present time they constitute distinct, wingless orders of insects. A general study of their morphology shows us that in both cases the winglessness and the peculiar build of these insects are both secondary characteristics, due to the assumption of the parasitic habit. In the case of the fleas, the life-history is so like that of the Diptera, or two-winged flies, that we do not hesitate to say that both have been derived from a common ancestor, a long way back in geologic time; indeed, some entomologists still place the fleas as a family within the order Diptera. In the case of the lice, recent researches have shown the very close relationship which exists between the two groups of biting lice (*Mallophaga*) and sucking lice (*Anoplura*), and, further, the less close but still marked relationship between both of these and the order Copeognatha or Psocids. Though most of the latter group are winged insects, yet a number of small wingless forms exist, such as the common book-lice and cabinet-mites (*Atropos*, *Troctes*, &c.), some of which eat hair, feathers, &c., and are even sometimes found on mammals. From some such form as these, with little doubt, the two types of parasitic lice have been evolved.

Having, then, dealt with those types of wingless insects which, by reason of their morphology, can be definitely associated with related winged forms and must therefore be considered as having been evolved from winged ancestors, there still remains another important group of wingless insects of a different type—viz., the primitive wingless insects—in which the study of their morphology fails to indicate any relationship to winged insects but rather points to a similarity with other classes of animals, such as the Crustacea, Myriapoda, &c. The weight of evidence is very strongly in favour of these forms being a small remnant of the original wingless ancestors of the winged insects; that is to say, they have remained more or less in the same stage of evolution as that indicated by the unspecialized larval forms of winged insects. Their soft integument, primitive morphology, and, above all, their lack of anything approaching a marked metamorphosis, all point to this conclusion; so that we cannot be far wrong if we follow the universal opinion of specialists in these groups at the present day and consider them as forming a distinct subclass, to which the name Apterygota (*i.e.*, insects evolved entirely without wings) is now generally applied.

The primitive wingless insects fall into three very distinct orders—so distinct, indeed, that some authors would make separate subclasses, or even classes, for each; but this, we think, is going too far. It is the purpose of these articles to try to interest readers of this *Journal* in these insects, which are not at all uncommon in New Zealand, and can be collected with very little trouble. So little work has been done on them here that at the present time one order is entirely unknown, while the total number of species described in the other two amounts to only about half a dozen altogether.

One interesting fact to notice is the close similarity between the representatives of these orders occurring in New Zealand and those found in Australia, particularly in Tasmania; where necessary in these articles the

related Australian representatives will be mentioned, in order to emphasize this point. The close affinity of the two faunas also points emphatically to their great geological age; for it is well known that the two countries have very diverse faunas in the higher orders, and only agree closely in the matter of their archaic types.

The three orders which constitute the subclass Apterygota, or primitive wingless insects, are the following:—

(1.) Order THYSANURA, comprising the bristletails, silverfish, and their allies, in which the abdomen consists of ten segments, ending in a pair of tail-filaments, or cerci.

(2.) Order PROTURA, comprising minute, cylindrical insects which live in soil; they have twelve abdominal segments, but possess neither antennae nor cerci.

(3.) Order COLLEMBOLA, comprising the springtails and allies, in which the abdomen consists of only six segments, and most of the species have a well-developed spring which enables them to jump about.

The first of this series of articles deals with the Thysanura only.

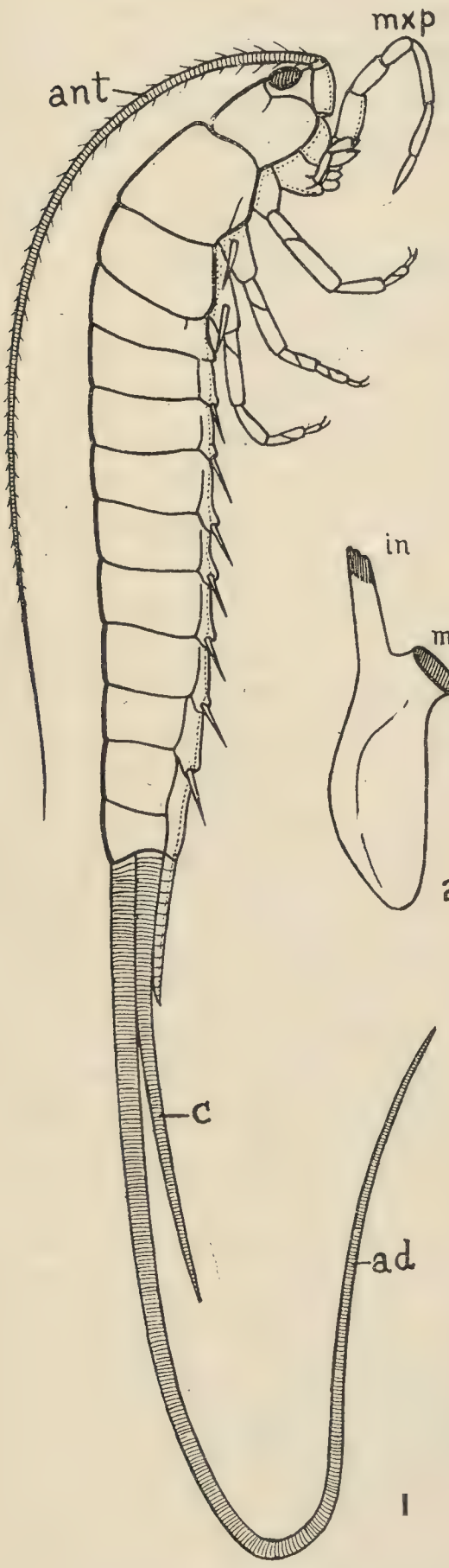
ORDER THYSANURA.

A familiar example of this order is the common silverfish (*Lepisma saccharina* L.), found everywhere throughout New Zealand in houses, but particularly in libraries and pantries, where it often does considerable damage owing to its decided taste for paper and cardboard. In the warmer and drier climate of Australia a related but larger and more active species carries on similar depredations; this is *Ctenolepisma longicaudata* Esch., originally described from South Africa. These insects can be at once recognized by their somewhat fish-like appearance, which is greatly heightened by their agile, wriggly movements and the slippery feeling experienced when handling them. They both belong to the family Lepismatidae, which contains the true silverfish and bristletails. There are, however, a number of other, somewhat diverse, types of insects included within the order, and grouped into no less than five families, which we may now proceed to consider in greater detail.

Family 1. MACHILIDAE. (Fig. 1.)

The insects forming this family are probably the most ancient types still existing, and show a considerable resemblance to Crustacea. They may be recognized by the dorsally arched or angulated thorax, the laterally flattened body, the immensely long antennae and tail-filaments, the long, leg-like maxillary palpi with no less than seven distinct segments, and by the presence of large compound eyes which meet on the top of the head. That the crustacean appearance of these insects is not due to a merely superficial resemblance is shown by the structure of some of their mouth-parts; in particular by their mandibles, which are of very remarkable form (fig. 2). The ordinary biting-mandible of an insect consists of a very hard, chitinous jaw-piece carrying strong teeth, but it is only in comparatively few insects (such as dragon-flies) that these teeth can be classed into two sets—viz., an apically placed set of incisors, and a more basally placed set of molars. Now, in the Machilidae (fig. 2) the incisors (*in*) and molars (*mo*) are placed far apart, and the mandible is then seen to be very closely similar to that of the higher Crustacea (Cumaceae,

Decapoda, &c.). A further and very interesting point of similarity is to be found in the presence of a movable style on the coxa of the middle and hind legs (*st* in fig. 3, *d*) in Machilidae; this appendage is plainly homologous with the "epipodite" of the Crustacean leg.



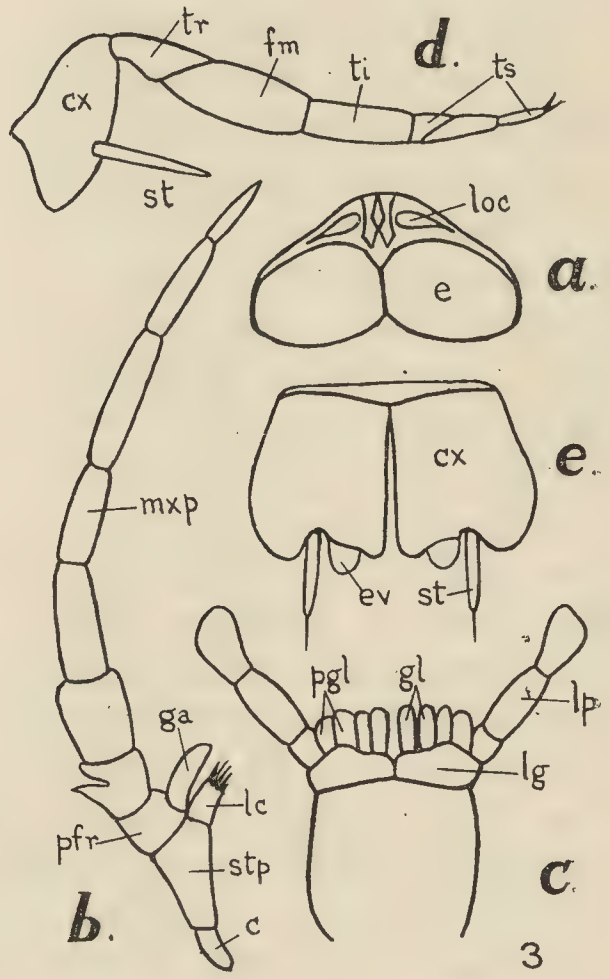


FIG. 1.—*Nesomachilis maoricus* n. g. et sp.: lateral view. Stephen Island, New Zealand. *ad*, appendix dorsalis; *ant*, antenna; *c*, cercus; *mxp*, maxillary palp.

FIG. 2.—Mandible of *Nesomachilis maoricus*, enlarged: *in*, incisor area; *mo*, molar area.

FIG. 3.—*Nesomachilis maoricus* n. g. et sp.: details. **a**, head from above, enlarged, showing compound eyes (*e*) and lateral ocelli (*loc*). **b**, maxilla, much enlarged: *c*, cardo; *ga*, galea; *lc*, lacinia; *mxp*, maxillary palp; *pfr*, palpifer; *stp*, stipes. **c**, labium, much enlarged: *gl*, glossa; *lg*, ligula; *lp*, labial palp; *pgl*, paraglossa. **d**, hind leg, enlarged: *cx*, coxa; *fm*, femur; *st*, style, or epipodite; *ti*, tibia; *tr*, trochanter; *ts*, tarsus. **e**, abdominal sternite: *cx*, coxite; *ev*, exsertile vesicle; *st*, style.

The ventral portions, or sternites, of the abdominal segments in Machilidae remain in a very primitive state. Each consists of a small basal plate, the true sternite (often reduced or absent), to which is attached a pair of huge coxites (*cx* in fig. 3, *e*), homologous with the coxa of the thoracic leg. The fusion of these two appendages in the middle line completes the chitinization of the body from below. Each coxite has a small appendage, or style (*st*), projecting from its distal end, thus again emphasizing its relationship with the coxa of the middle and hind thoracic legs. The eighth and ninth abdominal segments also carry genital appendages, which in the female form a primitive ovipositor; the last (or tenth) segment not only carries the two tail-filaments or cerci (fig. 1, *c*) characteristic of the order, but also a very much longer appendix dorsalis (fig. 1, *ad*), or median tail-filament, which aids the insect in jumping.

No Machilidae have so far been described from New Zealand, and only one rare species (*Allomachilis froggatti* Silv.) from Australia. Yet they are not uncommon, and should be looked for in rocky places near the seacoast, or on mossy tree-trunks in the forest. A number of isolated specimens have been brought to me from time to time from various parts of the Nelson Province, but on Stephen Island they can be found in fair numbers if carefully searched for. During a visit there in January, 1922, I used to find them by moving the rocks which abound on the high ridges, thoroughly disturbing the smaller stones, roots, and twining stems of *Muehlenbeckia* or other vegetable growths which often mat them together, and then watching the disturbed area carefully. Occasionally a small blackish insect, about $\frac{1}{2}$ in. long, would suddenly jump into the hollow made, and as suddenly jump out again. It takes a watchful eye and a quick hand to capture this agile creature, as it is capable of jumping a full yard, and makes consecutive jumps in varying directions. Some of the specimens appeared speckled with white; on examination this was found to be due to the rubbing-off of a dense coating of beautiful black scales which cover the whole body of the insect. Fig. 1 shows a side view of this species, greatly enlarged. It is a primitive Machilid, belonging to a new genus; a short description of it is given in the appendix to this paper, under the name *Nesomachilis maoricus* n. g. et sp.

One interesting point about these insects is the possession of peculiar vesicles (*ev* in fig. 3, *e*), numbering one or two pairs, on many of the abdominal sternites; these can be exserted when required, but their function is quite unknown. Another point is that the tongue, or hypopharynx, has a pair of side lobes which are believed by some biologists to be the homologues of the Crustacean maxillulae, though by others, with more reason, they are considered to be true paragnaths of the type found in decapod Crustacea. Anybody who could spare the time to keep a number of these insects alive in captivity, in a suitable cage of large size, would probably discover many interesting facts about their life-history, and might also succeed in obtaining fertile eggs, which, dealt with by a competent embryologist, would probably yield information of the utmost importance on the much-discussed question of the origin of insects as a class.

Family 2. LEPISMATIDAE. (Fig. 4.)

This family differs from the Machilidae in having the body markedly flattened from above downwards, this form of body being adapted to concealment in restricted places, such as under layers of bark, debris, &c. The head has long antennae, small compound eyes (sometimes absent),

and no ocelli; the end of the abdomen terminates in three long tail-filaments, as in Machilidae, but the middle one is not longer than the other two. The mandibles are of the ordinary biting type, with sharp teeth. The maxillary palpi are much shorter than in Machilidae, with only four or five segments. Styles are not present on the middle and hind coxae, but occur in many species on some of the abdominal sternites, together with exsertile vesicles. Most of the species have small compound eyes, but some are quite blind.

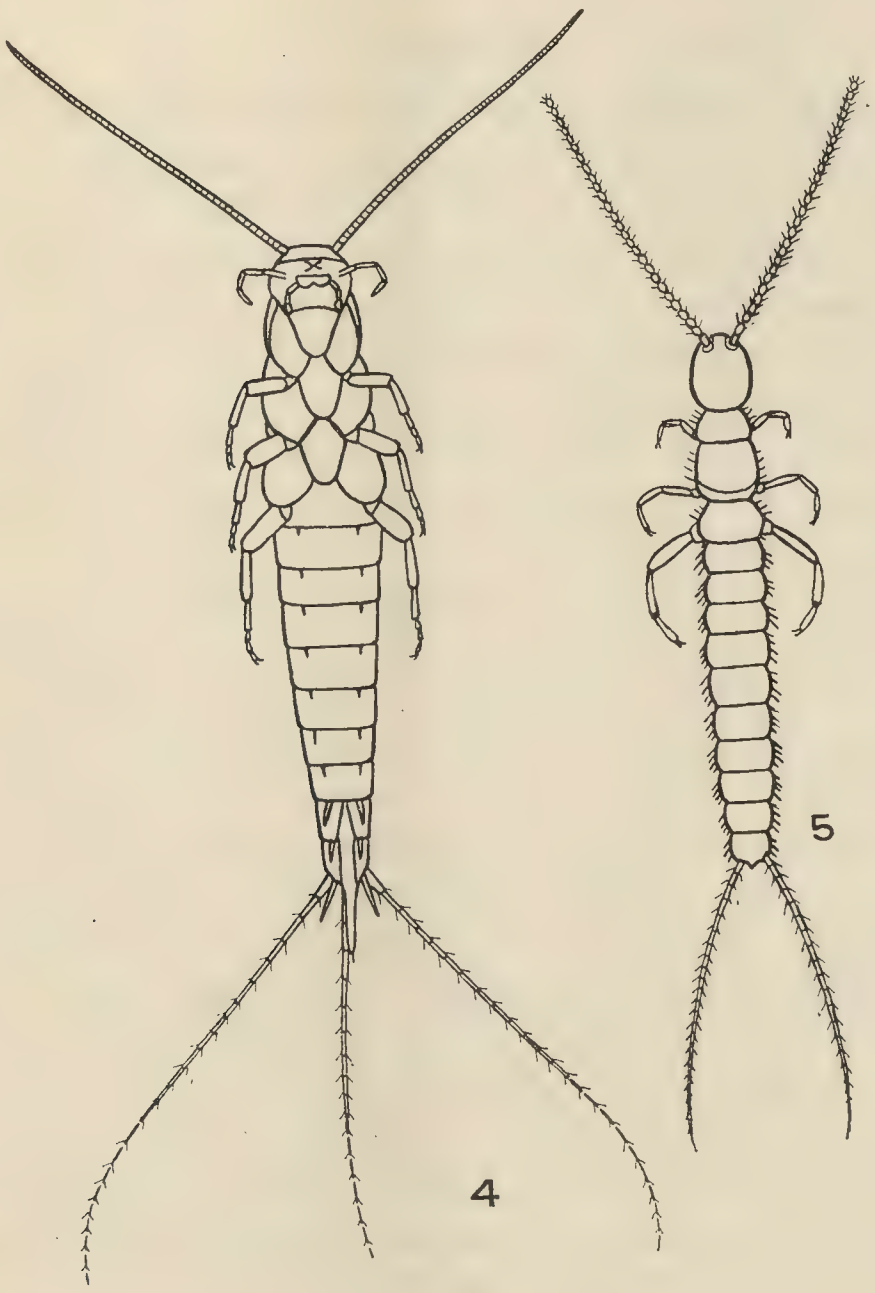


FIG. 4.—*Notolepisma zelandica* n. g. et sp.: ventral view, showing abdominal styles. New Zealand. Drawn by A Tonnoir.
FIG. 5.—*Campodea philpotti* n. sp.; dorsal view. New Zealand. Drawn by A. Tonnoi.

The true bristletails, which comprise this family, are fairly common in the bush both in New Zealand and Australia. A number of species have been found under the bark of forest-trees in Australia, and have been described by Silvestri. Other smaller species, quite blind, have been found in ants' nests; the best known of these is the excessively agile *Atelura cursitans* (Frogg.), which has given many a keen collector an exciting chase, round and round the nest at breakneck speed, before finally being cornered and captured. The common New Zealand species is described below; it is a primitive form, and belongs to a new genus, *Notolepisma*. It may be found running swiftly under the bark of forest-trees, especially old and partly decayed native beech (*Nothofagus*); it is of a pale, leaden-

grey colour, but this is entirely due to a covering of grey scales; the colour when the scales are rubbed off is pale creamy-yellow. No doubt several species new to science will be found in New Zealand when their habitats are fully explored.

In collecting these fragile insects, a tube of 70 per cent. alcohol or some suitable liquid fixing-agent should be carried, and the insect placed therein as soon as captured; otherwise the specimens will be so badly damaged as to be worthless for scientific study.

Family 3. CAMPODEIDAE. (Fig. 5.)

The two families already dealt with agree with the great majority of known insects in having the mouth-parts normally placed so as to project partly outside the head itself. We now come to a group of three more highly specialized families, in which the mouth-parts are entirely hidden within the head and are not visible from the outside. The first of these is the family Campodeidae, comprising the small, slender, and delicate insects of the genus *Campodea* and allies, found in debris, moss, soil, and rotten wood. They differ from the two previous families in lacking the median tail-filament; the abdomen is cylindrical, not flattened, and the segments are very clearly marked off from one another.

This family is particularly interesting from a biological standpoint owing to its close resemblance to the subclass Symphyla of the class Myriapoda, or centipedes and allies. The symphylous genera *Scolopendrella* and *Scutigerella* contain small centipedes which resemble *Campodea* very closely, but have legs on every segment; there are also important morphological differences in the position of the genital openings and in certain of the internal organs. The abdomen of *Campodea* usually has small styles on the sternites, as in the previous families, and exsertile vesicles are also frequently present. If the styles and coxites are really the reduced remains of original walking-legs, as seems highly probable, then the insects might be thought of as having arisen from a *Campodea*-like ancestor which had little or no differentiation between thorax and abdomen, and had legs on every segment of the body. This would involve the hypothesis of a common ancestor for myriapods and insects, and would controvert the evidence from Machilidae for an origin from Crustacea. There are still some biologists who favour the *Campodea* hypothesis, but the general trend of modern thought is rather towards the idea of a crustacean origin, most entomologists now considering the Machilidae as much more primitive than the Campodeidae. All we can be sure of is that the problem is not yet solved, and any new evidence that can be brought forward will be greatly welcomed.

No species of *Campodea* has yet been described from either Australia or New Zealand. Recently, Mr. A. Philpott discovered one of the largest known species of the family on the Mount Arthur Plateau, Nelson Province, at an altitude of 4,000 ft. This comparative giant measures no less than 7 mm., or over $\frac{1}{4}$ in., in length, excluding the tail-filaments and antennae, which together give it a length of well over $\frac{1}{2}$ in. The specimens were found in rotten wood, and are described in the appendix to this paper as *Campodea philpotti* n. sp., in honour of their discoverer. Most of the known species of this family only measure about half this size, and are so delicate that they should only be handled with a fine camel's hair brush.

Family 4. PROJAPYGIDAE.

This is a small family of very rare insects, forming a connecting-link between the true Campodeidae and the highly specialized earwig-like Japygidae. They have the tail-filaments shortened, composed of a few segments, and the antennae are also considerably shorter than those of Campodeidae. They should be searched for in the same places as Campodeidae. As Japygidae are quite well represented both in Australia and New Zealand, there is no reason why these insects also should not be discovered here in time.

Family 5. JAPYGIDAE. (Fig. 6.)

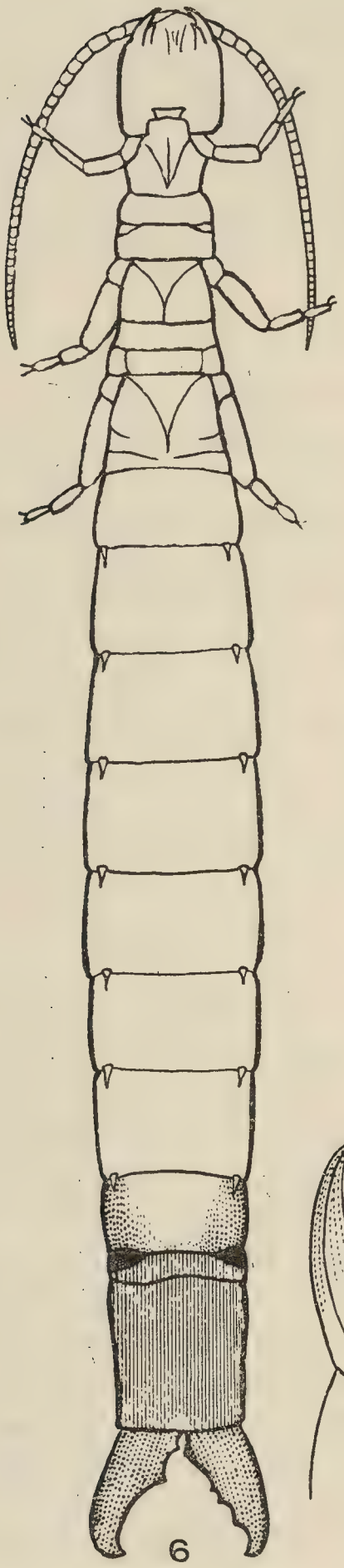
This family contains the most highly specialized of all Thysanura, in which the mouth-parts are concealed within the head, the antennae are comparatively short, with many small segments, the eyes are entirely absent, and the two tail-filaments, or cerci, have undergone a great change, being reduced to a single, strongly chitinized segment; the two cerci together form a strong forceps, somewhat resembling that of an earwig. The whole insect has a superficial resemblance to an earwig, but can be at once distinguished by its concealed mouth-parts, its soft, whitish integument (only the terminal segments of the body and the forceps being dark and hardened), and by the fact that, unlike the earwig, it has no power to telescope its abdominal segments one within the other. The head and thorax are small, not so wide as the abdomen, and the legs are short, the tarsi having only a single segment; styles are usually present on the first seven abdominal sternites.

It has always been stated that these insects have no excretory organs or Malpighian tubules. In dissecting a large specimen of *Heterojapyx*, however, I discovered the vestiges of a set of six such organs (fig. 7) arranged in the usual position at the anterior end of the hind-gut.

The genus *Heterojapyx* contains the giants of the order, the females of some of the species measuring up to 2 in. in length. Two species are known in Australia and one in New Zealand, all very closely similar to one another, but distinguished by the sculpture of the forceps (fig. 8). The largest of all is the Australian species *H. gallardi* n. sp., described in the appendix. It was discovered by Mr. Luke Gallard at Epping, a suburb of Sydney, N.S.W., and a number of specimens were sent to me for study. The New Zealand species, *H. novae-zelandiae* Silv., is not so large as this; the longest female I have seen is about $1\frac{1}{4}$ in. in length. Specimens of this rare insect have recently been taken by Mr. A. Philpott in Aniseed Valley, near Nelson.

The habits of these insects are very interesting. They burrow in deep soil, and may sometimes be found at a depth of 18 in. or more below the surface, going deeper in very dry weather. In wet weather they come to the surface, and hide under logs, rocks, or large stones. A very favourite position with them is to lie with the head and body just under the soil, but with the forceps just exposed, level with the surface; in this position they snap viciously at any insect which may happen to touch them, and sometimes succeed in capturing it and dragging it down under the soil, probably devouring it at leisure afterwards.

The movements of these insects in the soil are very like those of centipedes. They are often seen to curl round in a somewhat similar manner, and on one occasion a large female was found accompanied by



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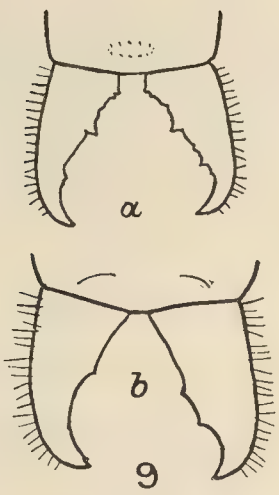

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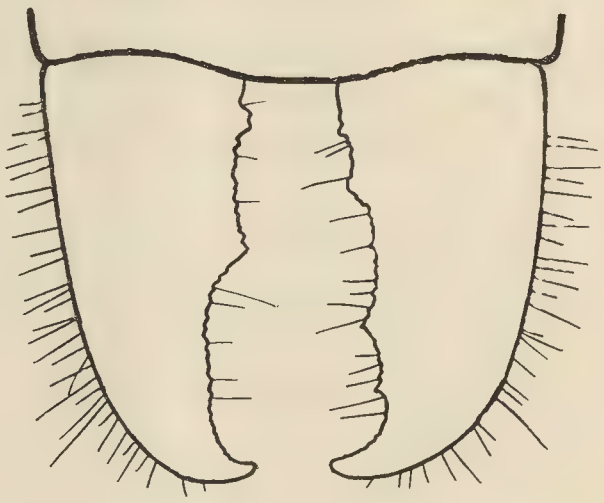

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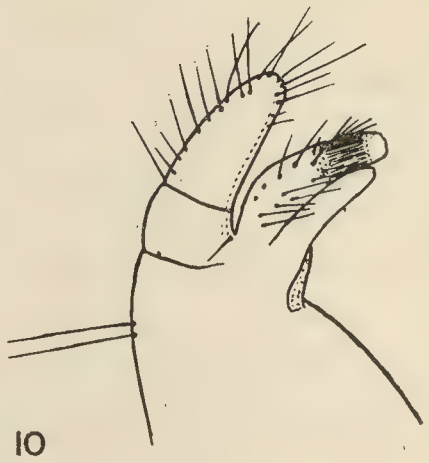


FIG. 6.—*Heterojapyx gallardi* n. sp.: ventral view, showing abdominal styles. Australia.

FIG. 7.—Vestiges of Malpighian tubules in *Heterojapyx gallardi* n. sp., at junction of mid-gut (above) with hind-gut (below). Four out of the six tubules are visible in the figure. Enlarged.

FIG. 8.—Forceps of *Heterojapyx gallardi* n. sp., enlarged. Note the asymmetry of the denticulation of the internal edges.

FIG. 9.—Forceps of (*a*) *Heterojapyx victoriae* Silv. (after Silvestri), and (*b*) *H. novaezealandiae* Verh. (after Verhoeff), for comparison with fig. 8. Note the symmetrical denticulation in *a*, the asymmetrical denticulation in *b*.

FIG. 10.—Maxilla of *Heterojapyx gallardi* n. sp., dissected out from head. To left, the internal lobe, or lacinia; to right, the external lobe, with two-segmented palp and bifid galea. Enlarged.

several young ones. It seems very probable that they lay their eggs in a clump and watch over them, taking care of the young. They are quite blind, and their antennae are kept continually moving over the ground as they progress.

Besides the gigantic species of *Heterojapyx*, much smaller species of the genus *Japyx* occur both in Australia and New Zealand, but so far only one of these has been described; they measure $\frac{1}{2}$ in. or less in length.

This article concludes with an appendix giving short descriptions of the new genera and species which have been mentioned in it.

APPENDIX.

Family MACHILIDAE.

Genus NESOMACHILIS n. g. (Figs. 1, 2, 3.)

A genus of the subfamily Meinertiellinae, with the sternites of the abdomen entirely absent, the ventral sclerites being formed entirely from the large coxites (*cx* in fig. 3, *e*). Head (fig. 3, *a*) with lateral ocelli large, pear-shaped; compound eyes conjoined for a short distance; scape of antennae very large, pedicel small; mandibles with broad basal portion, with short flat molar plate and narrow elongated incisor process with denticulate apex; hypopharynx with laminate side-lobes pointed apically; maxillae as in fig. 3, *b*, with a sharp process on outer side of basal segment of palp; labium as in fig. 3*c*, with distal segments of palpi slightly broadened and flattened. Thorax strongly arched dorsally, but without any marked angle between successive segments; prothorax closely embracing the head; middle and hind coxae with well-developed styles (fig. 3, *d*). Abdomen subcylindrical, with very large coxites, those of segments 2–9 carrying well-developed styles; a single pair of exsertile vesicles (*ev* in fig. 3, *e*) present on segments 1–9 respectively. Cerci shorter than abdomen; appendix dorsalis exceedingly long and strongly built.

Genotype: *Nesomachilis maoricus* n. sp. New Zealand.

Nesomachilis maoricus n. sp. (Fig. 1.)

Length of body 9–11 mm.; antennae about as long as body; cerci 4–5 mm.; appendix dorsalis 12–14 mm.

Body entirely covered with blackish scales, easily rubbed off so as to show the integument, which is creamy white.

Habitat: Stephen Island, N.Z. Found under loose rocks on high ridges, 14th January, 1922.

Type and series of paratypes in Cawthron Institute collection.

Family LEPISMATIDAE.

Genus NOTOLEPISMA n. g. (Fig. 4.)

A genus of the subfamily Lepismatinae, having a primitive form of body with no marked convexity or widening of thorax. Head with bidentate mandibles; maxillae with 4-segmented palpi (the original basal segment being aborted); labium with 3-segmented palpi, the distal segment greatly swollen, capitate. Antennae and cerci both shorter than body, appendix dorsalis shorter than cerci. Setae present round eyes and on sides and front of head; a fringe of setae along front margin of

prothorax; no dorsal setae present on abdomen. Abdominal sternites with small styles on segments 1–7, larger styles on segments 8–9. Cerci and appendix dorsalis with cylindrical segments much longer than wide.

Genotype: *Notolepisma zelandica* n. sp. New Zealand.

Notolepisma zealandica n. sp. (Fig. 4.)

Length of body 9–11 mm., of antennae 5–6 mm., of cerci 7–9 mm., of appendix dorsalis 5–6 mm.

Body entirely covered with pale shiny greyish scales, easily rubbed off, exposing the yellowish integument beneath. Antennae strong, cylindrical, composed of very numerous short annular segments. Cerci with 18–20 segments, all except the last strongly ciliated distally. Appendix dorsalis shorter, with 14–16 segments similar to those of cerci.

Habitat: York Bay, Wellington Harbour. Found under the bark of old native beech-trees (*Nothofagus fusca*), 20th March, 1921.

Type and series of paratypes in Cawthron Institute collection; also one paratype taken by Mr. J. G. Myers in same locality in May, 1924.

Family CAMPODEIDAE.

Genus CAMPODEA Linn.

Campodea philpotti n. sp. (Fig. 5.)

Length of body 5–7 mm., of antennae 3·5–4·5 mm., of cerci 3·5–4·5 mm. Antennae moniliform, ciliated, with 25–27 segments. Mandibles with four teeth. Cerci filiform, ciliated, with about 20 segments, each of which is considerably longer than wide. Styles and exsertile vesicles present on abdominal sternites 2–7.

Colour creamy yellow. Scales entirely absent.

Habitat: Mount Arthur Plateau, at 4,500 ft. elevation. Taken by Mr. A. Philpott in a rotten log, February, 1921, and December, 1922.

Type and series of paratypes in Cawthron Institute collection.

This species should perhaps form the type of a new genus, but the differences between genera in this family are so slight that it seems best to place it in *Campodea* pending a more detailed study of allied types.

Family JAPYGIDAE.

Genus HETEROJAPYX Silv.

Heterojapyx gallardi n. sp. (Fig. 6.)

Length of body—in males 30–35 mm., in females 35–50 mm. General colour a creamy white, segment 8 yellowish-brown, segments 9–10 and forceps rich brown to dark brown. Closely allied to *H. victoriae* Silv., from which it can be distinguished by the form of the maxillae (fig. 10) and forceps (fig. 8). The forceps of *H. victoriae* Silv. (fig. 9*a*) and *H. novae-zealandiae* Verh. (fig. 9*b*) are shown for comparison.

Habitat: Epping, near Sydney, N.S.W., August–September, 1919, also 1920–24; discovered by Mr. Luke Gallard, in deep soil.

Types: Holotype female, allotype male, and series of paratypes of both sexes, in Cawthron Institute collection.

In conclusion, I desire to thank M. André L. Tennoir for making the excellent pencil drawings from which figs. 4 and 5 have been prepared.

AGRICULTURAL IMPLEMENTS OF THE MAORI.

The Timo, or Grubber.

By ELSDON BEST.

Illustration by J. McDonald.

ALL the implements employed by the Maori cultivator of the soil were of a very primitive type. His digging-tool was a rude form resembling the "Highland spade" of Scotland, and his wooden spade, with the blade in direct line with the shaft, were by no means handy tools. A third and apparently a less widely used form was the *timo*, a rude wooden pick or grubber, employed in loosening the soil. It was fashioned from a forked branch, or a sapling having a branch providing the necessary angle. The illustration shows the manner in which the tool was used. Fashioned from hardwood, with a point hardened by seasoning or fire, it was certainly a

Cultivating with the *timo*.

useful implement for soil-loosening, but the kneeling position found necessary when using it must have been very tedious to the operator. The club-like end of the tool was often used as a clod-breaker.

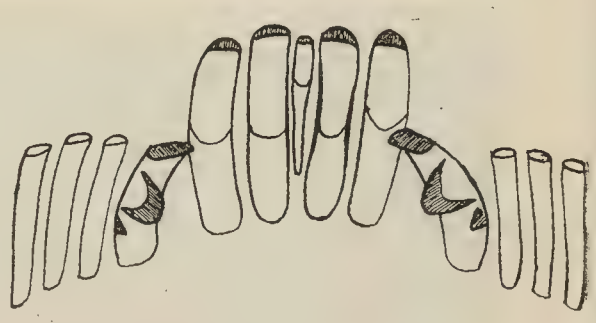
This grubber was much used on the west coast of the North Island, but was not common in some other districts, so far as I have been able to ascertain. The light cultivation *ko* (as distinct from the heavier breaking-up form) seems to have replaced it in some areas. Among the Matatua tribes the straight-lined implement termed a *awuwau* appears to have taken its place.

The Rev. R. Taylor gives an illustration of the ancient Egyptian hoe in his *Te Ika a Maui*. It closely resembles the *timo* in form, but such a primitive tool as this grubber must have been one of the first implements employed by tillers of the soil, and doubtless was widely known. Our Maori folk termed it a *tima* in some districts; *timo* seems to be an appropriate name, on account of the word meaning "to peck, to strike with a pointed instrument."

ZOOLOGICAL NOTES.

The Australian Eight-rayed Limpet (*Scutellastra chapmani* **Ten.-Woods**), by W. R. B. Oliver, F.L.S.

This Australian species would not concern New Zealand conchologists but for the fact that it has been listed among the molluscan fauna of New Zealand since 1873. The New Zealand record is based on some shells in the Dominion Museum. One, the type of Hutton's *Patella octoradiata* (*Cat. Mar. Moll. N.Z.*, p. 44, 1873), is labelled "West Coast, South Island," while three others are marked "Foveaux Strait." These labels are in the handwriting of Mr. Suter, who apparently attached localities to specimens from published information. There seems room for errors to creep in by this method. The only original label, a single specimen, bears the legend "*Patella stellaris*, H. Bay." The species is not certainly known to have been gathered by any New Zealand collector, and there can be little doubt that a mistake has been made, and the name should be omitted from the New Zealand fauna.



Radula of *Scutellastra chapmani*.

The species is found along the coast of New South Wales, Victoria, and South Australia, occurring on rocks near low-tide mark. It has been identified from the Janjukian series (Miocene) of Victoria.

Scutellastra perplexa has had an eventful history, having been placed successively in the genera *Patella*, *Acmaea*, and *Patelloida*. In the radula there are five centrals, the median one being small and apparently functionless; a single lateral on each side bears three cusps, and on either side of these are three narrow marginals. On account of the possession of a median tooth and of a porcellanous ribbed shell the species falls within the genus *Scutellastra*.

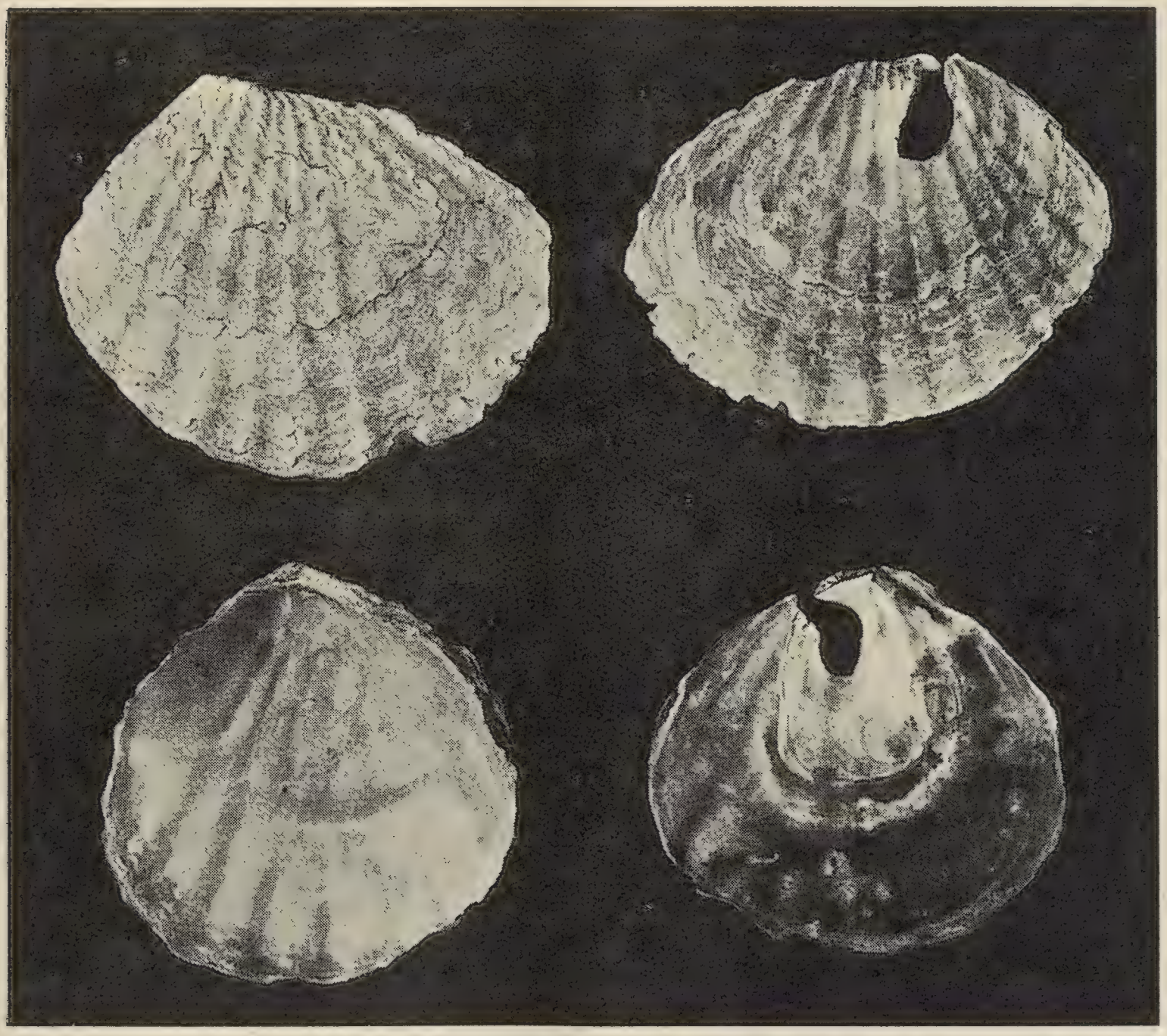
Full references to literature are given by Chapman and Gabriel in *Proc. Roy. Soc. Vict.*, vol. 36, p. 25, 1923.

The species was first correctly classified as a *Scutellastra* by Peile (*Pro. Mal. Soc.*, vol. 15, p. 15, 1922), while Iredale has recorded that Tenison-Woods's *Patella chapmani* is the earliest valid name (*Pro. Linn. Soc. N.S.W.*, vol. 49, p. 239, 1924).

Modification of Sculpture in Shells of Marine Mollusca, by C. E. R. Bucknill, L.M.S.S.A., Lond.

Every conchologist must have noted the wide variations of shell-sculpture to be met with in individuals of the same species of Mollusca, and assumed, with reason, that the divergence is due in most cases to environmental stress—a rather vague explanation, but one which may serve in lieu of a better. One of the best examples bearing out this hypothesis is the *Acmaea*

pileopsis (Quoy and Gaimard). In the juvenile state, when the shell is about 7 or 8 millimetres in length, we find that where the species lives in small sheltered pockets, on rocks weathering to a comparatively smooth surface, close to high-water mark, and not subjected at any time to more than the gentle wash of a spring tide, the shell is very thin, perfectly symmetrical in outline, and practically devoid of all sculpture. It is not surprising that this form has been described as a distinct species under the name of *Acmaea cantharus* (Reeve). It is to be found in Auckland Harbour, at Herne Bay, close to the mouth of Cox's Creek.



In direct contrast to these specimens, those occurring on the north-east side of Mount Maunganui, upon the rugged volcanic rocks, and exposed to the full force of the breakers, are thick in structure, irregular in outline, and sculptured with strong sharp radial lirae, the intervening sulci being correspondingly deep and well marked. Here there are two factors to be considered—one passive, the other active. The passive agent is the roughness of the rock, which results in a similar irregularity in the margin of the shell. The active agent is the pounding of the waves, which is responsible for the increased thickness of the shell and the exaggerated sculpture, usually accompanied by a remarkable flattening of the apex.

An excellent illustration of the passive influence of environment completely altering the sculpture is to be seen in two specimens of *Anomia walteri* (Hector), recently collected from Point Chevalier, Auckland Harbour,

by Mr. J. Bennet, late Government Inspector of Fisheries. These two specimens were each attached to the left valves of *Pecten medius* (Lamarck), and are remarkable not only in the fact that the sculpturing of each right valve is an exact cast of that of its respective host, with which it is in immediate contact, but that the external surfaces of the left valves of the *Anomia* present a similar mode of ribbing. The internal surfaces of all four valves, normally quite plain, also show the same ribbing and grooving as the external surfaces, but reversed—indicating very plainly the profound impression upon the nervous system of the animal that the mere contact of the edge of the mantle with the shell of a widely different species is capable of inducing.

In recording these fine specimens possibly some light may be thrown upon the problem of protective imitation in nature; but in any case we cannot fail to have our attention drawn to the need for careful examination of facts before venturing to announce a new species, which, after all, may prove to be merely an instance of adventitious variation.

In the third volume of the *Cambridge Natural History*, "Molluscs and Brachiopods," page 257, is figured "A specimen of *Anomia ephippium* (Linné), Weymouth, taken upon *Pecten maximus*, the sculpture of which is reproduced on the upper valve of the *Anomia*, and even upon a younger *Anomia*, attached to a large specimen." A curious parallel, indeed, that a window shell attached to a scallop on the south coast of England should be represented in New Zealand by two almost identical species under precisely the same circumstances!

Occurrence of *Brama raii* in New Zealand, by W. J. Phillipps, F.L.S., F.R.G.S.

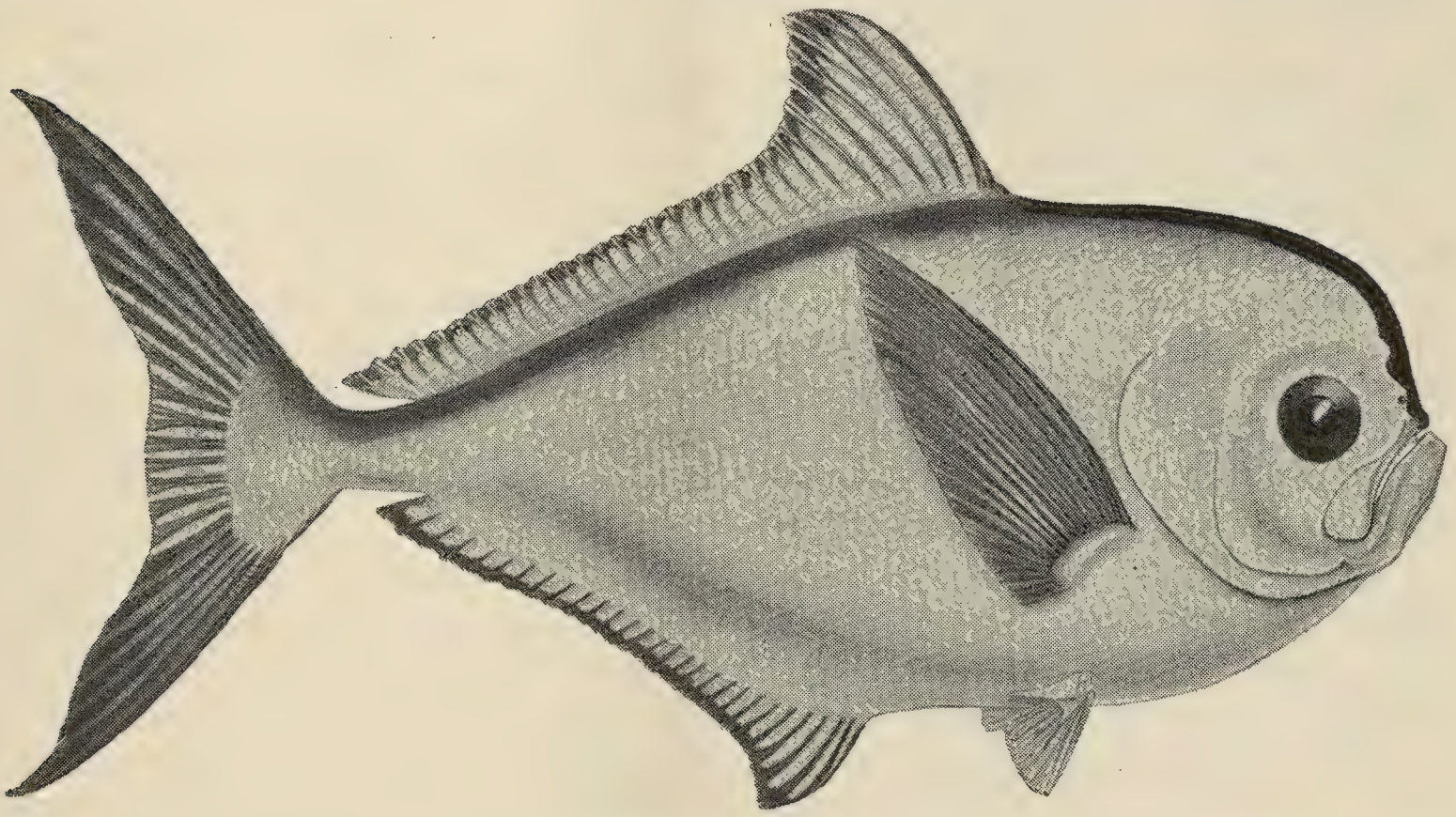
Family BRAMIDAE. Ray's Sea-bream (*Brama raii*).

Among the fishes on exhibition from New Zealand waters in the Dominion Museum are two specimens of *Brama raii* (Ray's sea-bream) the history of which is unknown. McCulloch (*Check-list Fish, N.S.W.*, 1921, p. 54) states that the only record of the species from New South Wales is unsatisfactory; and for a time I was doubtful whether the species had ever been taken in our waters. No record of Ray's bream has ever been given from South Australia, though McCoy (*Prod. Zool. Vict.*, dec. xiv, p. 127, pl. 133) states that this remarkable fish appeared at Portland, Victoria, in considerable numbers in April, 1884, being previously unknown to fishermen. The recent acquisition of three specimens—one from Napier, one from Queen Charlotte Sound, and one from Plimmerton—removes all doubt of the existence of this world-wide species in New Zealand. The excellent illustration of Ray's bream reproduced here was found among the drawings of the late F. E. Clarke, and is in itself an interesting record, being labelled "Hokitika beach, 12th April, 1872. D. 3 + 32. P. 2 + 19. V. 1 + 5. A. 2 + 27. B. 7. H. :: B. & T. :: 2 :: 9."

Ray's bream is remarkable for a variation in many of the body characters by which most species of fish are generally distinguished. The colour also appears to vary considerably in many parts of the world. All examples secured by the Dominion Museum were of an intense irridescent blue colour, the iris of the eye being golden, and the pectoral and caudal

fins tinged with yellow. The Plimmerton specimen appeared to have had certain red markings on its head. Couch (*British Fish*, 1877, vol. 2, p. 129) gives an illustration of a fish with a dark-green back, the sides and under-surface being flesh-colour tinged with green.

The differences in the shape of the profile of the head appear to be outstanding. The two stuffed specimens in the Dominion Museum exhibit the same upright convexity above the mouth as is portrayed in the above figure. In each of the three other specimens, however, the profile of the head is less upright, and appears to agree more nearly with the species as figured by McCoy (*loc. cit.*).



Ray's sea-bream (*Brama raii*).

A short description of the Dominion Museum specimen from Napier is as follows :—

D. 3 + 32 ; P. 2 + 19 ; V. 1 + 5 ; A. 2 + 27 ; B. 7 ; L. lat. 93.

Body extremely compressed, the deepest portion being at the origin of the anal, and not at the origin of the dorsal as portrayed in most drawings of the fish. Total length is 1 ft. $3\frac{1}{2}$ in., which is three times the greatest depth. The eye is large, its diameter being 4·5 times the length of head, which is contained 4·5 times in the total length. The vent is situated at the base of the ventral. A row of large conical teeth on edge of upper jaw, with smaller ones innermost. Two large conical teeth on each side of lower jaw, the rest smaller. Teeth present on the vomer and palatines. Caudal deeply forked with about 24 rays, those near the upper dorsal and lower ventral margins nearly four times as long as those of the middle. Lateral line indistinctly marked.

Toxotes squamosus (Hutton, *Trans. N.Z. Inst.*, vol. 8, p. 210, 1876) is most probably the same species. The type, unfortunately, is not to be located among collections in the Dominion Museum.

SAP-STAIN IN TIMBER OF *PINUS RADIATA (INSIGNIS).*

By J. S. YEATES, M.Sc., National Research Scholar, Victoria University College.

IN connection with an investigation undertaken for the State Forest Service on the sap-stain of white-pine (*Podocarpus dacrydioides*), my attention has been drawn to the presence of sap-stain in timber of *Pinus radiata*. Some trees of this species, grown at Inglewood, and uprooted in a gale during March, 1924, were examined about the middle of May. Broken or cut surfaces had in nearly every case developed a considerable amount of blue stain. Inquiries at the mill of the New Plymouth Sash and Door Factory showed that some trouble had occurred there in timber of *Pinus radiata*. Freshly sawn boards, if left more than a day or so in close, unventilated stacks, were nearly always attacked by the "black-rot," and trees left on the ground for any great period after felling became discoloured, and the timber sawn from them was blue and "lifeless." This attack of unsawn logs is of especial importance, for it means that the men cannot be employed felling trees when conditions do not allow of immediate transport to the mill.

From Mr. A. R. Entrican, Forest Products Engineer to the State Forest Service, some very badly infected timber was obtained about the same time, together with an intimation that this disease is causing a good deal of trouble throughout the country.

Although sufficient time has not yet elapsed to enable certain aspects of the matter to be decided, some particulars as to the nature of sap-stain, especially in *P. radiata*, may be of interest. *Pinus radiata* is not yet milled in very great quantities, but seems destined to become in time perhaps the most important timber in this country. Any knowledge of its diseases will therefore be of more value as time passes.

The staining of timber may be due either to chemical action or to the activity of a fungus which penetrates the wood. Chemical stains in general show no discrimination between heart-wood and sap-wood. Fungus stains, on the other hand, are in general restricted to the sap-wood, since in this part of the wood starch and sugars are present. Probably, moreover, the occurrence of tannins and like substances in the heart-wood is a condition which protects that part from the fungus.

In the case of fungus-attack, a spore, blown about by air-currents, is deposited on the surface of the timber, and if conditions, such as moisture and warmth, are favourable it proceeds to germinate. The thread-like hyphae which it produces grow and penetrate the timber, more especially along the wood rays which run from the centre to the bark of the tree. From the ray cells the fungus sends branches into the tracheides of the wood. The fungus which most commonly produces sap-stain in Europe and in America uses for food hardly anything but the starches stored in the wood, leaving the walls of the cells almost intact. In consequence the timber loses but little in strength. Unfortunately, however, the appearance of light-coloured wood is spoiled, and since conditions have been favourable for the sap-stain fungus there are likely to be present other and more harmful species of fungus which flourish under the same conditions as does

the sap-stain fungus. It is a remarkable fact that the sap-stained wood has a blue colour, although the fungus when seen under the microscope is distinctly brown in colour.

Methods of controlling such stains, and fungus-attack in general, consist essentially in rendering conditions on or in the wood unsuitable for the germination of the spores. A certain amount of moisture on the surface is absolutely essential for spore-germination. Accordingly, if timber be well exposed to warm, dry air until it is fairly dry, fungus attack is most unlikely. Wet weather, lack of space, haste in despatching timber, and handling-costs all tend to render this method unsatisfactory. In some cases kiln-drying is found useful, though it is too expensive for ordinary timbers.

Another factor of importance is the acid or alkaline reaction of the moisture on the timber. Most of the fungi which attack wood prefer sap with a reaction which is slightly acid, and grow only poorly if the acid be neutralized. On this are based the most useful methods yet known of combating fungus-attack. The freshly sawn timber is immersed for some time in a solution with an alkaline reaction, then drained and stacked.

The solution most commonly used is one of 5 per cent. to 10 per cent. of sodium carbonate in water. In solution this salt is hydrolized so that a certain amount of sodium hydrate is present to neutralize the acids of the wood. Borax is slightly cheaper than sodium carbonate, and seems from preliminary trials to be more satisfactory than the carbonate. Quicklime has been tried in America and found most satisfactory in checking fungi, but was ruled out on account of the discoloration it produced in the wood. It seems to me this objection would be removed if slaked lime be used, preferably as milk of lime, and tests of this are at present being carried out. If lime be at all effective it would certainly be the best alkaline bath to use, on account of its extremely low cost.

All of the above methods based on neutralizing the acids of the wood are liable to failure in one respect that seems to have been overlooked. A board coming from the alkaline bath has a weak solution of alkali on the surface, while the sap inside the board is still acid. If the timber be close stacked this sap is bound to diffuse out through the wood and neutralize the alkali, leaving conditions again favourable for growth of the fungus. In such cases the best method known is to use a bath of some substance toxic to the fungus. Mercuric chloride, zinc chloride, or sodium fluoride, in solutions of 0·1 to 0·5 per cent., are generally found effective. The former is open to the objection that it is very poisonous, and should not be used where the treated surface is later to come into contact with articles of food. According to Boyce, an American authority, this treatment is the only one that is satisfactory when green timber is shipped in the close hold of a vessel. It seems possible, however, that flooding the hold with carbon dioxide and so displacing the oxygen would provide a remedy under these circumstances.

THE SAP-STAIN IN PINUS RADIATA.

As mentioned above, the stain is found both in unsawn logs and in sawn timber of this tree. Most of what follows applies chiefly to the sawn timber, since very good specimens of the stain have been found in it.

Fig. 1 is a photograph showing part of a badly stained tree cut transversely. It will be noticed that the dark colouring which represents the stained wood stops at the edge of the heart-wood, which is here distinctly

lighter in colour. This specimen was taken from a branch of a dead standing tree. Whether or not the sap-stain caused the death of the tree cannot be said, though most probably death was due to other causes.

In green trees of *P. radiata* which have been felled and sawn on the ground the fungus enters the wood chiefly at the cut ends, more especially if two such ends are left close together so that drying-out is prevented. Again, where the bark is damaged so that it separates from the wood a most suitable nidus is provided for the stain. In about three weeks the stain will easily penetrate from $\frac{1}{2}$ in. to 1 in., provided the weather be suitable.

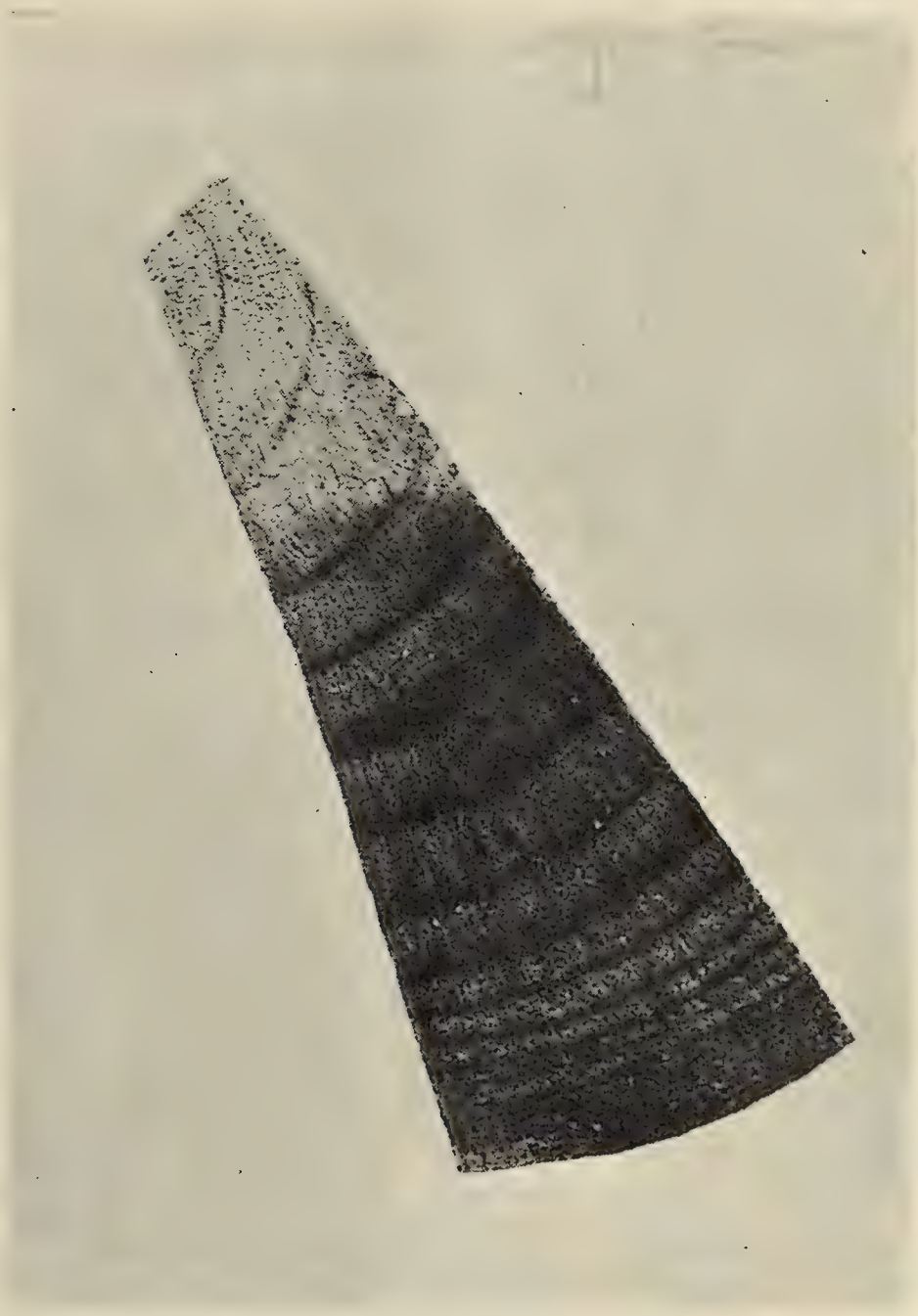


FIG. 1.—A sap-stained branch of *Pinus* cut transversely. The stained wood is darker in colour than the unstained portion (heart-wood). Natural size.

It is, however, on sawn timber that the damage is most plainly seen. Boards which have lain for some days in close contact after being sawn develop dark bluish-black patches where the fungus attacks them. Here again damage is confined to those parts which have been sawn from the sap-wood. A board is sometimes seen which has been cut from the margin of the heart-wood and has patches of this side by side with the sap-wood. Sap-stain, if present, will be found to affect probably all of the sap, but never any of the included heart-timber.

The dark surface of the affected area bears numerous black spots, each about the size of a pin-point. Examined with a good magnifying-glass,

each spot is seen to be a short bristle with a swollen base, the whole having a length of about 1 mm. ($\frac{1}{25}$ in.). These are the fruiting-bodies, or perithecia, of the fungus. In the swollen basal part ascospores are produced in large numbers. They escape at the tip of the long beak and are scattered by the wind. In fig. 2, A, are shown two such perithecia as seen under the microscope, while 2B shows a few of the spores.

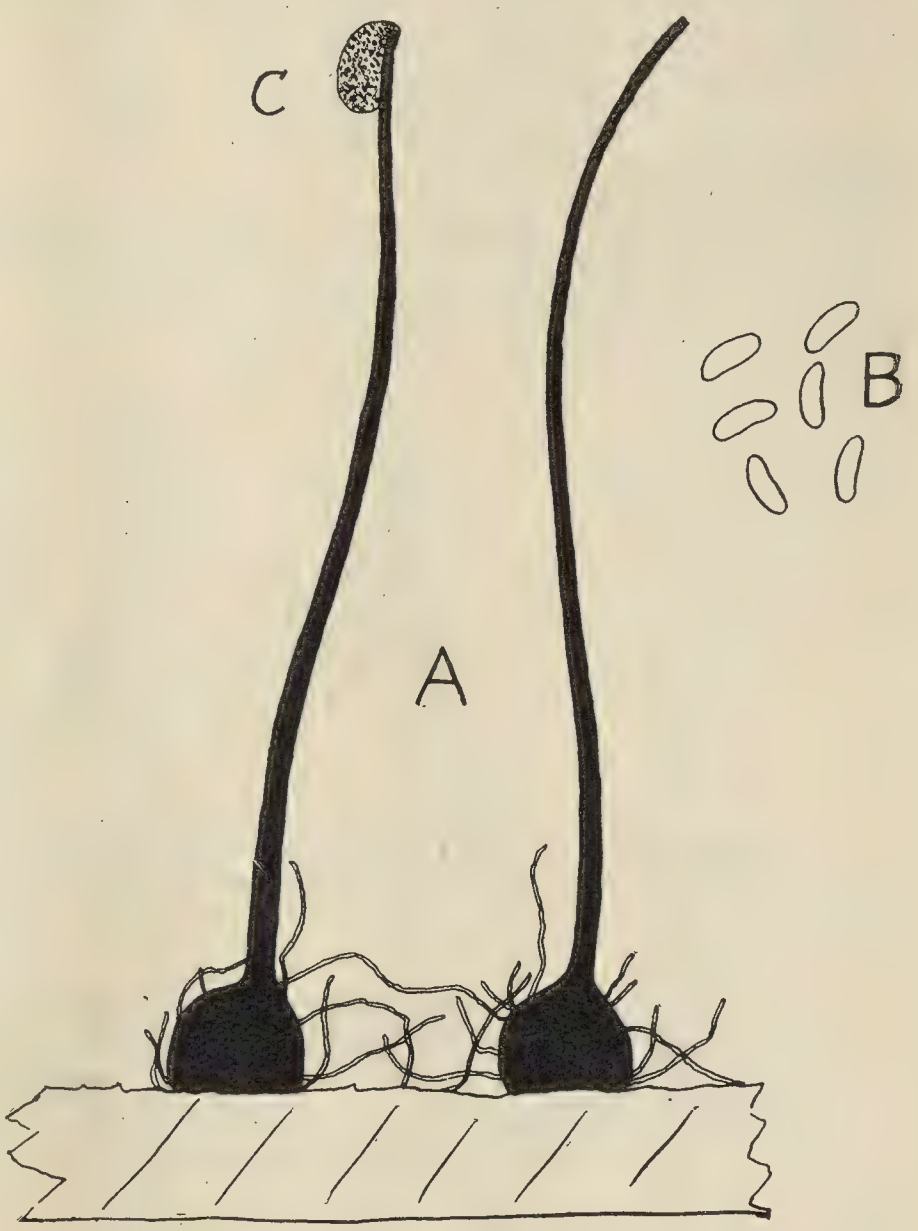


FIG. 2.—A. Perithecia of *Ceratostomella* on surface of *Pinus radiata* (semi-diagrammatic); × 80. B. Spores of *Ceratostomella*; × 1,100. C. Extruded spores in a droplet of moisture on the end of the beak of the perithecium.

When sections of the stained timber are examined microscopically, fungus hyphae are at once obvious. These hyphae run chiefly along the wood rays, giving off branches which penetrate into the tracheids. The resin-ducts found near the limits of each year's growth are closely crowded with hyphae. Fig. 3 represents a radial section of such timber. The tracheids run vertically in the figure, and here lie behind the medullary ray. Several fungus hyphae are shown, both in ray-cells and in tracheids. The fungus has been slightly dotted in the figure merely in order to make it show up plainly amongst the elements of the wood. In nature the hyphae are of an even light-brown colour, with occasional septa as shown at D. Several cases are shown in the figure, where the fungus passes through the bordered pits between adjacent cells (B, C). Although this seems to be the usual method adopted, yet occasionally, as at A, the hyphae penetrate the wall of the tracheid.

All the features of the fungus mentioned above—the long-beaked perithecia with their ascospores, the method of attack on the wood, and the nature and behaviour of the hyphae in the wood—enable it to be identified as *Ceratostomella*, several species of which are found to cause sap-stain in other countries.

Since this is the common type of sap-stain, studied intensively in Europe and America, the methods of control used in those countries will probably be found the most satisfactory in New Zealand. On the other hand, climatic conditions here may demand or allow of other methods of control. At present there are being tried out several of the methods mentioned above.

For literature and specimens in connection with this matter I should like to thank Mr. A. R. Entrican, Engineer in Forest Products to the State Forest Service; and for specimens or other help, Professor H. B. Kirk, and Mr. Jackson, manager of the New Plymouth Sash and Door Factory.

I have later received from the State Forest Service timber of nine species of *Pinus*, all badly affected with sap-stain. The species were *Pinus austriaca*, *P. Laricio*, *P. pinaster*, *P. ponderosa*, *P. insignis*, *P. Coulteri*, *P. Sabiniana*, *P. sylvestris*, and *P. strobus*. In every species except *P. ponderosa* the fungus causing the stain was readily identified as *Ceratostomella*. The specimen of *P. ponderosa* had been planed all over, so that there remained no fructifications by which the fungus could with certainly be identified. There can, however, be little doubt that *Ceratostomella* was present here also.

In a covering letter the following details were given concerning the timber: The trees were grown at Homebush, Canterbury, on clay land at an elevation of 800 ft. They were felled in August, 1923, sawn at the mill

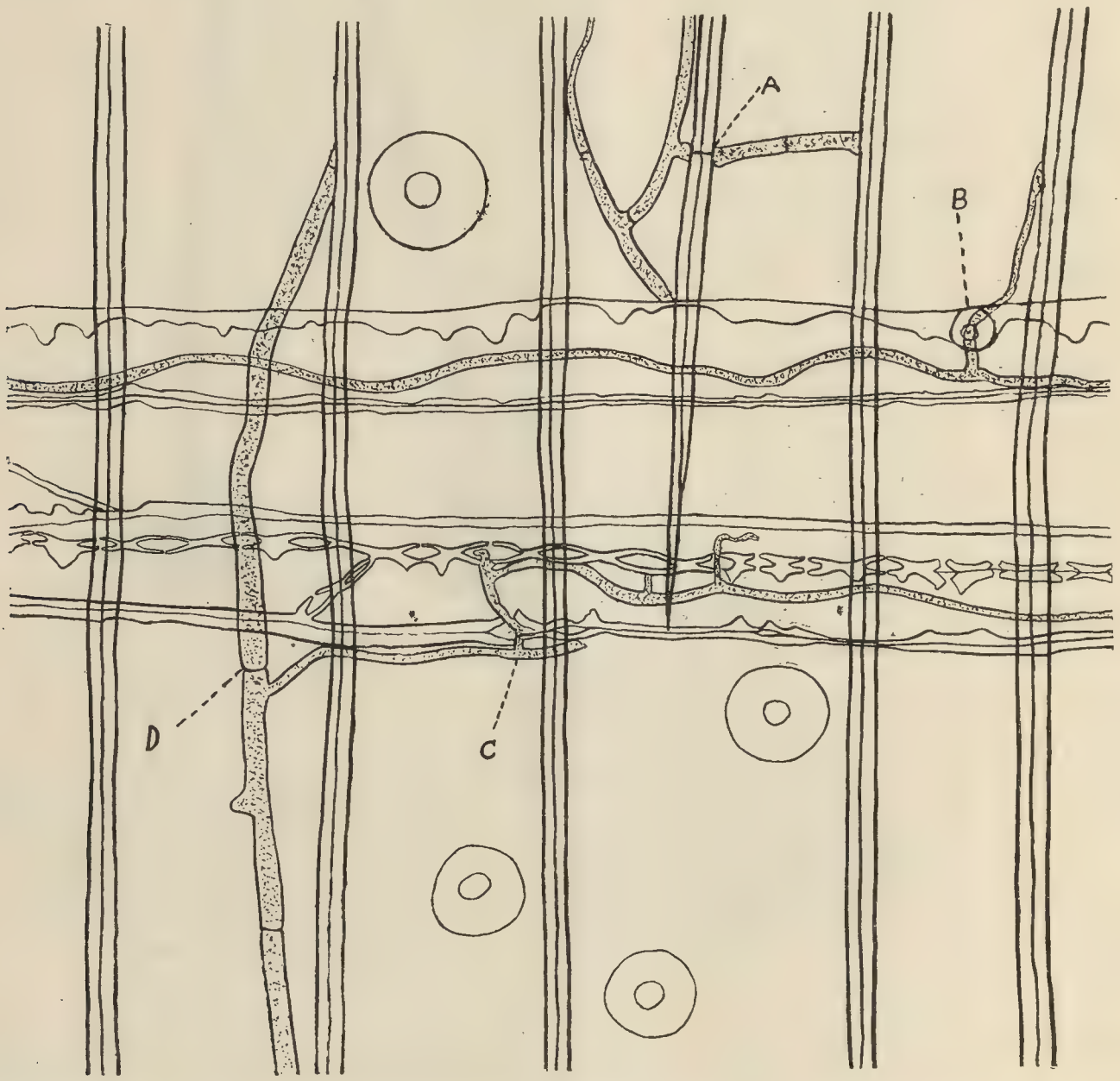


FIG. 3.—Radial section of timber attacked by the sap-stain fungus *Ceratostomella*; × 450.

on the 5th September, and on the 6th September were stacked in a large room (70 ft. by 36 ft. by 30 ft. high), the boards being separated by wooden strips 1 in. square. After three months in this room much of the timber was found to be covered with "black mildew"—the perithecia of *Ceratostomella*. Other specimens in the same stack and other varieties (of *Pinus?*) under similar conditions were reported not to have been attacked.

In view of the general occurrence of *Ceratostomella* as shown by these specimens, it is plainly important that methods of control on a commercial scale should be evolved in readiness for the time when present extensive plantations begin to mature. Laboratory experiments, though indispensable, can be taken only as a starting-point for the study of control measures on a commercial scale.

The above-mentioned timber and the details of its treatment were secured by Mr. W. T. Morrison, Conservator of State Forests, Christchurch.

SPARTINA-GRASS, AND ITS INTRODUCTION INTO NEW ZEALAND.

By H. H. Allan.

The story of the rise and spread of *Spartina Townsendii*, a robust grass forming great sheets of vegetation on tidal mud-flats along the south coast of England, and also on the Normandy coast, is one of the romances of plant-life. It is a story, too, that has many important economic bearings. The first part of the present article is based on a paper, "*Spartina* Problems," by Professor F. W. Oliver, F.R.S. (1920), from which all the quotations are taken. I have gratefully to acknowledge the kindness of that botanist, and of Professor R. H. Yapp, of Birmingham University, in sending me papers and information on the subject. The second part gives observations made on *Spartina* plantings at Foxton, made by Mr. K. W. Dalrymple, of Bull's, whom I have to thank for much information and help in preparing the paper.

Occurrence in England and Normandy.

Spartina stricta, which forms low-growing spreading mats of herbage, has been known in Europe since early times. In 1829 a second species, *S. alterniflora*, presumably introduced accidentally from America, was found in Southampton Water. A third species, *S. Townsendii*, appeared there in 1870, and has since increased in an astounding manner, and spread to various localities along the south coast of England. Since its discovery in 1906 on the Normandy coast it has behaved in the same fashion there. It has been planted on the Dovey salt marshes (Yapp, 1922, p. 22; 1923, p. 102), and the experiment is being watched with close attention. "In addition to being a botanical phenomenon of the first order, perhaps unique in the recorded history of vegetation, the spread of *Spartina* is raising economic problems which will have to be grappled with sooner or later. Though still in the phase of youth, *Spartina* already occupies dozens of square miles of mud-flats in pure stands which continually get denser and denser. There seems little risk of error in asserting that in the future this area will expand to hundreds or thousands of miles. Subject to climatic limitations, wherever there is mud there will be *Spartina*. It is time for us to learn something about the properties of this amazing plant."

Spartina Townsendii is thought to be a hybrid between the other two species. It is not known in any other part of the world, and its vigour of growth lends support to the theory; but if, as Professor Oliver thinks almost certain, it is largely propagated by seed, its constancy of form is remarkable. The matter needs intensive study. The plant luxuriates on the soft mud of tidal estuaries within about 1 metre of high-water mark. "At first single isolated plants appear, presumed to be seedlings; each plant spreads laterally by means of stolons to form a circular or oval patch; the rate of growth in any direction being from 2 ft. to 3 ft. per annum under favourable conditions. In this way the expanding tufts soon unite into strips with open passages between—like a jig-saw puzzle approaching

completion—and finally meadow into practically continuous stretches covering acres of mud."

ECONOMIC IMPORTANCE.

The importance of *Spartina* as a reclaiming agent becomes obvious from the above remarks, but this power of the plant to act as a colonizer of soft mud creates the possibility of danger to navigation. "When parts of a tidal estuary are banked off and removed from tidal action, by so much is storage space for water diminished; and this amount will be lacking for scour at the ebb. The result is that the channels become choked and navigation suffers." Where such results are likely to accrue *Spartina* plantation should not be lightly undertaken; but much more information is needed before definite pronouncements can be made.

FIG. 1.—Margin of *Juncus maritimus* var. *australiensis* association, showing average level of high tide.

As a feed for stock *Spartina* has distinctive features. "Horses, sheep, and cattle eat it with avidity, and habitually make their way on to the *Spartina* meadows almost before the tide has run off. Farmers speak well of it, except that it gives an undesirable flavour to milk. As the grass remains standing on its roots throughout the winter till April, it forms a most convenient reserve feed that can be cut as required."

A good deal of preliminary work has been accomplished with a view to determining the properties of *Spartina* as a raw material for paper, with the results that harvesting methods have been arrived at, and the difficulties to be overcome in producing a good quality pulp have become more or less clear. "It is hard to believe that at some future time, when *Spartina* has spread into all the muds of our shores, this plant will not find a use in the papermaking world. Allowing for an average yield of 2 tons dry weight per acre, enough *Spartina* is already present in these waters to feed a mill all the year round with 100 to 150 tons per week."

"From every point of view full knowledge is required, alike whether the plant be regarded as a botanical phenomenon, a weed which seriously threatens navigation, or a gift of Providence capable of being put to a variety of uses."

Introduction into New Zealand.

In 1913 a number of plants of *Spartina* were obtained by Mr. Dalrymple from Southampton Water and planted out in small clumps on the Foxton mud-flats in the tidal estuary of the Manawatu River. The clumps were considered to consist of specimens of both *S. stricta* and *S. Townsendii*, but unfortunately it is not certain that the latter has

Fig. 2.—Large patch of *Spartina stricta*, becoming uncovered by tide. Tidal channel in foreground, *Juncus* association beyond. Sandhills on farther side of Manawatu estuary.

bestalished itself. All the clumps that have flowered have proved to be *S. stricta* (this identification being confirmed by Professor Yapp, and at Kew). It may be, indeed, that no *S. Townsendii* was planted, but a close watch is being kept, and any occurrence of this species will be recorded. The clumps were put in bare mud below high-tide level (fig. 1). One clump (*cf.* fig. 2) has thriven markedly. By 1915 it had formed a dense mat 1·8 m. across. The area was again visited on the 11th February, 1923, when the patch was found to measure 12·8 m. by 7·2 m. The sheet was dense and short in the central portion, which was becoming mounded by accumulation of mud, and luxuriant on the margin of the deeper tidal channel. There were a few flowering-culms that proved the clump to be *S. stricta*. On the 16th March, 1924, the patch had increased to 14·3 m. by 7·4 m., the longer diameter parallel to the tidal channel. Some slight progress had been made towards crossing the channel here about

1 m. below high-tide level. This patch and several of the others were then flowering rather freely, especially towards their margins. The other patches had also increased, but not so conspicuously. One clump, for example, measured 3·6 m. by 1·9 m. These small patches were also more open in character. At this date some seed of *S. Townsendii*, kindly sent by Professor Oliver, was sown under light litter, which was netted down. On a visit, 23rd May, 1924, it was found that all seed had been shed from the culms, but no sign of seedling plants was seen, nor had germination occurred in the sown patch. A number of small clumps were noticed established in the immediate neighbourhood of the planted clumps, but it could not be determined whether these were from seedlings or rooted pieces carried by currents. These new establishments are being charted for record.

INDIGENOUS ASSOCIATIONS.

The salt-swamp associations at Foxton are fairly typical of the formation in New Zealand in general, as described by Cockayne (1921, p. 66), and no detailed description is necessary, but the broad features may be given, in view of the competition likely to occur between them and the *Spartina* plantings. *Juncus maritimus* var. *australiensis* and *Leptocarpus simplex* are dominants, both forming very extensive dense sheets, the latter usually seaward of the former, and less in extent. There is not wanting evidence that in this locality the *Juncus* invades the *Leptocarpus* sheets and tends to subdue them. The areas of bare mud are not extensive, and into the *Spartina* neighbourhood border the tidal channels. Between the margins of the dominants and the bare mud there may be patches of *Scirpus americanus*, *Salicornia australis*, or *Triglochin striata* var. *filifolia*, the latter pair with or without other small species. Certain of the *Spartina* patches have now approached closely to the margins of the various species mentioned, and careful measurements and notes have been taken with a view to studying future changes. Present observations suggest that the *Juncus* will take advantage of the rising of the level of the mud by the *Spartina* and invade its territory.

CONCLUSION.

Mr. Dalrymple's experiment would appear to raise questions of considerable interest and importance, especially if *S. Townsendii* can be established in addition, and future progress will be systematically watched.

In the present area no great extent of mud is available for the *Spartina*, and the chief matter may be the question of the relative aggressiveness of the indigenous and the introduced species. Where areas of very extensive mud-flats occur, as in Kaipara Harbour, and where the navigation problem is not likely to become important, there would seem to be a field for interesting and important investigations, and it is hoped to enter upon these.

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THE STRUCTURE OF THE ATOM.*

By Professor C. COLERIDGE FARR, D.Sc., F.N.Z.Inst.

ALTHOUGH the subject of the structure of the atom engrosses the minds of the most distinguished physicists and chemists, and indeed mathematicians, to-day, and has created general interest, our real knowledge of atomic structure is of exceedingly recent origin. In a way it may be said to date from as recently as 1911; but, of course, its evolution can be traced much further back, and for the beginning of atomic ideas we shall have to go as far back as Democritus. But the vague ideas which prevailed early in the history of science need not trouble us at all.

To obtain a clear idea of what is meant by the structure of an atom one must first have a clear conception of what is understood by an element. Chemical analysis of the materials of which the earth is composed forced it upon us that, as far as purely chemical processes are concerned, all the varied objects and materials around us are resolvable into about eighty-seven more simple ones, which are known as the elements, but in the main it had, until lately, proved to be impossible to resolve these eighty-seven simple elementary bodies into still more simple substances. Taking then, say, a piece of copper, let us in imagination proceed to cut the copper up. It remains copper; each piece has the same chemical and physical properties as the other pieces; and, however finely we were to carry on the subdivision, until a certain limit was reached this state of affairs would prevail. The material would still be copper, though getting smaller and smaller in its pieces. However, there is a limit to which we can go in this process, and possibly it is a much smaller limit than many persons are aware of. It is possible by one means and another to go on cutting up the copper pieces into smaller and smaller bits until they reach the size, say, of little spheres about one-hundred-millionth of a centimeter in diameter. Each of these smallest pieces into which an element can be broken is an atom. And here let me ask you not to worry at all if I use figures which may seem to indicate extreme

* Lecture before Wellington Philosophical Society, 22nd October, 1924.

smallness or vast greatness. Such things or numbers are small or great only to our crude ideas of smallness or greatness. What seems to us, with our finite ideas and impressions, to be inconceivably small is large enough for Nature to build within its boundaries a very universe of complexity; and what may appear to us to be enormously great is small enough for Nature to hold in the hollow of her hand and to cause it to dance about like the motes that people the sunbeam. And so we have come to this lump of copper. To us it is small; it is, indeed, as I have said, one-hundred-millionth of a centimetre in diameter. The rest of my address will be devoted to trying to show you how the Great Architect of the Universe regards it.

It has been found that this small piece of copper has so far resisted all attempts which have been made to break it up into smaller pieces, and it has been and still is called the "atom" of copper. So it is with most, but not quite all, of the other elementary bodies. So far they have not been further subdivided. But, whilst this is so, it does not mean that we have been unable to penetrate into the structure, but merely that the structure, which we now know a great deal about, is there, and we know it and can to a certain extent picture it, but in most, but not all, of the eighty-seven elementary bodies it has resisted all our efforts to smash it.

As I shall be speaking altogether of these atoms, and as, to many of you, one one-hundred-millionth part of a centimetre is so small that it is hard for you to picture a thing of that size having any structure at all, let me again ask you to put aside all ideas of smallness. Put on the magnifying-glasses of your imagination and imagine it to be as large as you like, and a great part of the difficulties will vanish.

A very important step in unravelling the nature and structure of the atoms of the different elementary bodies was taken when Sir J. J. Thomson discovered the nature of the "cathode rays." These rays are the streams of light which pass down an exhausted tube through which an electric current is passing. There were many speculations before the year 1896 as to what the nature of the rays was, but it remained to Sir Joseph Thomson to show that the current was carried down the tube to a very large extent by carriers whose mass was only about one two-thousandth part of the mass of the hydrogen atom, the lightest atom known, and that the carriers were of the same mass whatever the residual gas in the tube might be. Thus a tube filled with hydrogen, or with oxygen, or with chlorine gas, and subsequently re-exhausted to a low pressure, gave the same mass of carrier, and this carrier moved with a prodigious (to us) speed down the tube. Neither the mass of the carrier nor the speed at which it moved down the tube depended upon what sort of gas had been put into the tube. This discovery was indeed an epoch-making one, for it was the first time that the same entities—the carriers—had been derived from such dissimilar things as oxygen, hydrogen, or any other gas that could be introduced into the tube. Man had got a very little below that atom. He had not broken it up, but he had knocked a chunk off the outside of it, and the bits he knocked off, whether they came from oxygen or from any other gas, were in all respects the same. Researches which have gone on since have most fully confirmed this, and have shown that the bits so knocked off artificially by passing an electric current through a rarified gas are nothing more than disembodied electric spirits. In a sense the atom had been broken up, but only temporarily; for it immediately repaired itself by seizing one of the many stray pieces that it has since been found are very common inhabitants of the terrestial atmosphere.

The next great step in the march of discovery towards the ultimate structure of matter was made about the same time as that of the nature of the cathode rays. Becquerel discovered that certain very heavy elements, notably uranium and thorium, emitted radiations of a kind not at that time known. I have said—and it is important to bear the fact in mind—that these radiations came only from the very heavy elements. The uranium atom is indeed the heaviest one we know, being 238 times as heavy as the lightest, hydrogen ; and thorium is similarly a very heavy-atomed element. The discovery of radium is very often ascribed to Professor Curie, but that is only true in a restricted sense. It was found that some ores of uranium were more active in the radiations which they emitted than pure uranium, and this led Curie to search in these ores for a substance more active than uranium. After very patient and most laborious research he finally isolated from an enormous mass (some tons) of uranium residues a tiny spot of radium. He looked for that which was causing these residues to be so active in their radiations, and he found an almost invisible grain of matter with the most intense properties. It, too, proved to be an element, whose atom was amongst the heaviest known.

But for most of the very complete knowledge we now have of the nature of the radiations coming from these heavy-atomed elements we are indebted to the experimental genius of Sir Ernest Rutherford. I have here an almost invisible amount of radium, and can show you the bulk electrical effect of the radiations, and they, or one of them, also have a photographic effect. Rutherford very soon systematized these radiations into three separate parts, which he called the alpha particles (he originally used the words "alpha rays," but as their nature became more apparent the term was altered), the beta particles, and the gamma rays. Of these the elucidation of the character of the beta particles came first ; they were much more amenable to such physical treatment as would render their nature clear. They proved to be nothing other than cathode rays ; only, unlike cathode rays, they were not generated by the passage of an electric current down an exhausted gas-tube, but came out spontaneously from these heavy-atomed elements. A good deal later the alpha particles were shown to be very much more massive things than the beta particles ; indeed, whereas the beta particle had only one two-thousandth part of the mass of the lightest elementary atom, the alpha particle had a mass four times as heavy as the hydrogen atom. These, too, were shot out from the atoms of the heavy elements. The gamma rays were shown to be of the nature of light-waves, but about one ten-thousandth of the length. More than this was soon found out. Both the alpha and the beta particles travelled with what to us would be enormous velocities, the former passing through space with a velocity up to about 12,000 miles a second, and the latter up to so great a speed as 170,000 miles a second. Moreover, the alpha rays were charged with positive electricity, and the beta particles were negatively charged, as too, of course, are their counterparts the cathode-ray particles. The gamma rays proved to have no electrical charge. Besides being eight thousand times as massive as the beta particle, and being positively charged, while the beta particle was negatively so, the alpha particle was found to carry a positive charge numerically twice as great as the negative one which the beta particle carried.

Thus we see that the heavy-atomed elements—the ones now known as the radio-active elements—are continually occupied in slinging off at least two different kinds of bits—the massive, heavy, positively-charged alpha

particles, and the light, negatively-charged beta particles. It could hardly be supposed that under these circumstances these heavy atoms should remain as they were, unchanged by such drastic happenings; and Rutherford and Soddy boldly announced that these radio-active atoms were examples of elements disintegrating—elements, that is to say, which were, like the Roman Empire, falling to pieces by the immensity of their own greatness. One can only devoutly pray that the British Empire in its turn may not share the fate of a radio-active atom; but supposing that such a world-wide disaster could happen, perhaps some analogies may add to the clearness of what I am trying to explain.

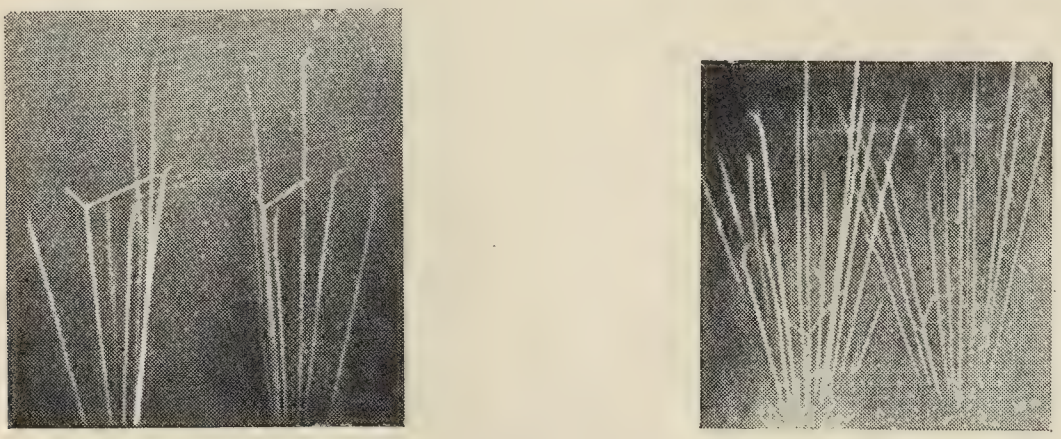
Conceive, then, the British Empire throwing out of itself the little Dominion of New Zealand. Such a thing might rightly be described as a cataclysm, more especially if the ejection took place at 12,000 miles a second. So is the ejection of an alpha particle from any of the radio-active elements—say, radium. The remains of the British Empire after the ejection of New Zealand could not possibly bear that name. It would surely be a degenerate thing—a less weighty Empire. So it is with the radium atom: it is no longer radium, but something with a weight in its own world, which is less influential by the loss of this particle. It has become degraded on the atomic scale, and that atom which has lost this alpha particle is no longer a radium atom, but the atom of a temporary element which was called "radium emanation" by Rutherford at a time when its nature was in some doubt, but which Ramsay suggested later should be called "niton," a name which Rutherford, the discoverer, never used. He had now given this gas—for it is a gas—the suitable name of "radon."

But the flying alpha particle which was ejected so unceremoniously—the thrown-out New Zealand of my analogy—what becomes of it, travelling through space at 12,000 miles a second, as it does? It is charged with two units of positive electricity, and in this excited condition it cannot settle down to a humdrum life. Changes in Government are numerous, and follow one another with surprising rapidity. It has two Ministerial portfolios to fill. One Premier after another gets called to Government House, but before he can pick up a suitable Minister of Finance he is himself knocked off his perch. Finally a Premier succeeds in establishing himself, and then makes frantic efforts to establish his colleague. One after another is tried, but after a short term of office the Colonial Treasurer is booted out, as was his superior officer, the Premier, before he had effectually dug himself in. The end of all this strife and electrical excitement is the firm establishment of the two Ministers in their official and proper seats, and a stable Government begins. The ejected New Zealand becomes a little nation, and the alpha particle, after its struggles to pick up two "electrons," becomes a helium atom.

Though it travels with such great speed (12,000 miles a second), the alpha particle's mad career through space can be traced for a little way—about 7 or 8 centimetres. As can be readily understood, the time occupied by so moderate a journey at such high speed would be described by any human as exceedingly if not inconceivably short: it would be, indeed, about one-hundred-millionth of a second. Many examples could be brought which would show that Nature does not consider one-hundred-millionth of a second so short a time that she need do nothing in it. To her it is quite long, and the natural events occurring in such a time are more numerous than those of which the ordinary unassisted senses of mankind would cause him to be conscious in many lifetimes. The track of one of these

alpha particles shot out from radium can be photographed; and it may help you to understand how a photograph of so quickly flying a thing can be obtained by remembering that the track of a bullet fired into a mass of soldiers would be visible long after the bullet had passed by the wounded men lying on the ground. As with the alpha particle, so with the bullet, a time would come when its velocity had been reduced so much that it could no longer penetrate the human body, and its track would abruptly cease. For the wounded soldiers of the bullet we have only to read the wounded atoms of the gas through which the alpha particle is passing, and perhaps you can see in a way how such a photograph has been obtained. It is to Sir Ernest Rutherford's extraordinary experimental skill that we owe our knowledge of the life-history of an alpha particle.

And so we see that these radio-active elements give us a further insight into the inner structure of their atoms by what has been described as their incurable suicidal monomania, their habit of throwing out bits of themselves and of changing by the process. For the atoms must be composed of these pieces. These alpha particles and beta particles must indeed be the bricks and the mortar of which the atomic structure is built.



A. B.

FIG. 1.—A, double photograph of forked alpha-ray tracks in oxygen; B, double photograph of forked alpha-ray tracks in helium. (After Blackett.)

The next great step forward in the history of the elucidation of the structure of the atom was taken by Rutherford in 1911, though, of course, there were many intermediate steps. The atoms of all the eighty-seven known elements are known to be electrically neutral bodies—that is to say, if they are built up of bodies such as alpha and beta particles there must be an equal total quantity of positive and negative electricity. It was owing to the investigations of what has been called the "scattering" of the alpha particles by the atomic structures through which they pass in their headlong rush through space that Rutherford was enabled to form a picture of what the internal nature of an atom must be like. In photographs of the tracks of an alpha particle there are, in some of the tracks, very abrupt changes in direction, and Rutherford investigated cases where the alteration of direction of motion was almost complete. The preliminary work which Rutherford did was repeated with greater accuracy a couple of years later by Dr. Marsden and Dr. Geiger.

Looking again at the photographic tracks, it will be noticed that many of the tracks are perfectly straight, and yet the flying alpha particle passed through many hundreds of thousands of atoms on its way, but was hardly—indeed, not visibly—deflected from its straight course. The track in the photograph is the picture of the line of damaged atoms through which the particle has passed—the wounded soldiers of my analogy; and the

line of them is continuous—not one here and there, but an unbroken line; so there must have been very many of them. The atoms through which the particle passed did not deflect it from its path, but it wounded them, or they could not have been photographed. Here and there, however, there is an abrupt change, and sometimes it is very abrupt.

There were many developments on the way to the great generalizations on which I am trying most to concentrate your thoughts. One of these developments was the elucidation of the character of the beta particles. I have said that they were of the nature of cathode rays—disembodied electrical spirits of a mass of about one two-thousandth of that of the hydrogen atom; and, like the cathode rays, each carried what is, as far as is at present known, the fundamental negative charge of electricity.

FIG. 2.—Photographs of the tracks of beta particles shooting through air. (After Wilson.)

Both the beta particles and the cathode-ray particles are called also by the name "electrons." Corresponding to these electrons there is another fundamental entity with which we must at once make acquaintance. It has been recently named a "proton." It is, in a very limited sense, the counterpart and antithesis of the electron. Both the electron and the proton are charged electrically, but the proton has a positive charge, whilst the electron has a negative charge. These charges are equal and opposite, and added together make outside them an uncharged thing. But here the opposite similarity ceases. The electron has for most purposes a negligible mass. The proton is a massive thing—just a very little bit less than the mass of the hydrogen atom. It is not, that is to say, so massive as an entity as the alpha particle I gave already mentioned. That had a mass four times the hydrogen atom's mass, or very nearly that, whereas the proton has a massiveness of just a little less than the hydrogen atom's mass; indeed, an electron and a proton together make up together exactly the massiveness of the hydrogen atom. Scientific investigation has now gone so far that it is certain that all atoms are built fundamentally of electrons and protons.

From the behaviour of the alpha particle as it traversed the atoms of the gas through which it was shot out, Rutherford pictured the atom as a

very diaphanous, open-structured affair—indeed, a sort of "solar system" in what humans might be tempted to call the minutest miniature—though, as I have said, smallness and greatness have no significance to Nature. He conceived the atom of an element as being a structure in which all the positive electrification was concentrated in a small but very massive nucleus at the centre. Surrounding this, some of them at immense relative distances, were sufficient electrons to make the whole atom appear as if it had no electricity connected with it: a neutral, unelectrified thing to all appearance from the outside, yet one which, once you got inside it, bristled with electrical forces. The straight path of the heavy alpha particle through such a structure as this can now be readily understood, as well as the sudden changes of direction sometimes to be noticed. For, to roam again in the regions of larger analogies, which for some reason are perhaps more easily understood than things which, like the atom, are so seemingly small, let us imagine an atom whose outside diameter is that of the solar system. (Indeed, there are now known to be very many points of resemblance between an atom and the solar system.) The planets under our luminary's control are of different sizes, ranging from Mercury to Jupiter in size; but in the solar system I am asking you to picture to yourselves let them all be of the same size—say, the size of our earth—but let the different planets move in the orbits that the real ones at present occupy. Imagine, then, a wandering body about eight thousand times the size of the earth suddenly shot into such a system at a speed of 12,000 miles a second: one can certainly understand that something would happen. A 28-lb. shot striking a pea in mid-air will itself hardly feel the impact; but it is not so with the pea. It is the same with this body of eight thousand times the mass of the earth striking one of the planets that I have asked you to imagine. The eight-thousand-times thing will go straight on in its path, but the integrity of the atom—that is to say, of the central sun and its attendant planets considered as one unit—will be damaged.

That is the story of the straight lines that the track photographs tell. But what about the kinks? It was these kinks that caused Rutherford to formulate the solar-system kind of atom, which has been so fruitful in its results. Other designs of atom have been suggested, but they failed to account for th se sudden bends. The bends are caused by the eight-thousand-times body passing near the central and massive nucleus. That, indeed, *is* massive enough to bend the intruder from its path, though the little planets cannot do so. If the eight-thousand-times body—another name for which is the alpha particle—passes near the massive core it is abruptly turned, like a comet round the sun; but if it passes only through the remote outskirts the obstacles it meets are few and far between, and not massive enough to turn it from its path. All knowledge that has so far been obtained points to the fact that the atoms of the chemical elements are solar systems in the infinitesimal, but no less perfect on account of their smallness. Indeed, if uniformity be a test of perfection, they are in their way more complete, as the planets in them are all of the same size, though differing in numbers from element to element.

Many years ago Prout, who was much laughed at in his day for saying so, enunciated the proposition that the relative weights of the various elements were whole multiples of the weight of the hydrogen atom; for example, that the weight of the carbon atom is twelve times that of the hydrogen atom, and the bromine atom is eighty times as heavy, whilst the

uranium atom is 238 times as heavy. Prout was by no means so far wrong as his contemporaries thought. In Rutherford's early work—indeed, in the same paper as he enunciated his theory of the nuclear atom—he stated that he believed the number of electronic planets to be about half the atomic weight in the case of any element which might be mentioned: that is to say, for helium, with an atomic weight 4, the number of electronic planets (or, more shortly, of electrons) would be 2; and in carbon, with an atomic weight of 12, it would be 6. Of course, since we know that all the atoms appear as non-electrified bodies under ordinary circumstances, this is the same thing as saying that the number of protons (that is of positively charged units) at the centre necessary to counteract the electrical effect of those electrons would be the same as they are in number—that is, 2 in the case of helium, and 6 in the case of carbon.

At the time (1911) that Rutherford was working at the subject he had a young Oxford student named Mosely working with him at Manchester. Mosely was working on what is called the X-ray spectra of the various elements, and he proved in a way that did not admit of dispute, and which has been accepted all the world over, that Rutherford's inference was very nearly right. In the time available it is impossible even to indicate the way in which Mosely arrived at the result he did. But from Mosely's work we have been enabled to conclude that the atom of each distinct element is distinct from every other in at least two ways—first, that the number of planetary electrons which the atom of one kind of element contains is different from that which another has; and, second, that the intensity of the positive electrification in the centre of each kind of stem is the same for each kind, but differs from element to element. And, more than this, Mosely's work enabled us to say how many planetary electrons there were for each kind of element, and therefore also what the intensity of the positive electrification at the centre was, for the number which represents one also represents the other. Mosely was, I believe, only twenty-three when a German bullet brought his short but most magnificent career to an end. But his work will endure for all time, for the now well-known atomic numbers (sometimes called "Mosely's numbers") will perpetuate his name in the ages to come, associating it with one of the most important discoveries at a time of scientific advancement when great and far-reaching discoveries were not uncommon.

We have seen that there are, first, electrons; then we saw that there are protons, which are to some extent their counterpart. They carry an equal but opposite electrical charge, but are roughly two thousand times as massive as the electrons Then, thirdly, we saw that there is also a thing called an alpha particle, which, though it is positively charged like a pr ton, is about four times as massive, being about eight thousand times as massive as the electron and it carries a positive charge. We have seen, too, that of these entities, electrons (in the form of beta particles) and also alpha particles are shot out from the heavier-atomed elements, which are themselves degraded in the scale of atomic dignity or weightiness by the process. I have pointed out that the track of the mighty alpha particle as it ploughs its way through the atomic maze is straight, whilst that of the light and airy but at the same time very voluminous beta particle is bent by every obstacle it meets, for none of them are lighter than itself.

The straight track of the alpha particle through the terrific crowd of atoms through which it passes—for it meets many millions of them—indicates a very open structure for the atomic building, a structure as open

as that of the solar system, in which a few planets and a central sun occupy in reality only a small portion of that total space which we should rightly describe as the "solar system." So it is with the atom, which consists of a few protons massed together, and an equal number of electrons acting as planets round them. Truly, one is inclined to say that the most solid thing we can think of—for instance, iron—is not so solid as it looks; but in saying so it must be remembered that, after all, our eyes were designed for the things of everyday life, and hardly for "seeing" atoms with. Nature endowed us with brains capable of making the proper microscopes to see them, and owing largely to the genius of Rutherford it has been done.

And so we see the atoms of hydrogen, of carbon, of bromine, of whatever other element you like, as merely differing from one another by the intensity of their central charge and by the corresponding number of planetary electrons going round it, and we have from Mosely's work the value of the central protonic charge and the equal number of planetary electrons. The number of free protons at the centre of the hydrogen atom is one, and surrounding it is one solitary el ctron. Helium, the next heaviest, has two protons at the centre and two el ctrons as planets. Lithium has three protons and three el trons; and so on, up to the heaviest we know, uranium, which has ninety-two protons and ninety-two electrons. It will thus be seen that the total number of elements possible, from hydrogen to uranium and including them, is ninety-two, and that they are all accounted for save five, whose Mosely, or atomic, numbers are 43, 61, 75, 85, and 87. It is, of course, possible that elements may exist which have a higher atomic number than uranium, but if they do they will certainly be radio-active elements, for all those at the latter end of the scale are radio-active, down as far as and including polonium; and, seeing now what their structure is, it is not surprising. For we must regard them as most complica ed solar-system atoms, containing nuclei with as many free protons at the centre as are represented by their atomic number, and with an equal number of planetary electrons, circulating in perhaps most complicate i systems of orbits. It is likely, then, that such systems should now and then burst—and they do.

But can anything be learned about the structure of the nucleus. Rutherford has shown that it is possible to get to within about one-million-millionth of a centimetre of its centre. That, of course, is a long, long way inside the atom itself, which has its centre there and its outer limit one hundred thousand times as far away. In these latter days scientific men have learned not to be daunted by either small or great size, but to accommodate their methods of thought by looking at the great as of moderate dimensions and the small in the same way.

I have pointed out that the number of protons (free and effective ones) at the centre of the different atoms are given by their atomic numbers. But their atomic weights are otherwise. Thus hydrogen, taking oxygen as 16 (as is convenient), has as its atomic weight 1·008; helium, exactly 4; lithium, 7. Why is this? The hydrogen atom—the lightest atom we know—consists of a proton at the centre and one planetary electron, and its weight, taking oxygen as 16, is 1·008, of which the planetary part is about 0·0005, leaving 1·0075 for the proton. It would seem, therefore, that there are four protons in the helium atom to make its atomic weight up to 4. But if we take four protons we get 4·030 for the weight of the central part, which wants four electrons stuck on to it somewhere or other to make it electrically neutral to the outside world—and I suppose there is nothing

in this world much more neutral than a helium atom—and sticking these four on would add on another 0·002, making the weight just four times the weight of the hydrogen atom, which consists of one proton and one electron. But the weight is *not* four times that of hydrogen: it is one-quarter that of oxygen; and if you take oxygen as 16, you must not take hydrogen as 1, but as 1·008; and these figures are accurate. Then, again, we have seen that the helium atom has only two planetary electrons, not four; and, moreover, the alpha particle which was shot out from the radio-active atom only picked up two electrons to become a full-fledged helium atom. You will remember my referring to ejected New Zealand's efforts to obtain a Premier and a Minister of Finance. Where, then, are the other two, and what function do they fulfil? The answer is that the other two are buried somewhere in the nucleus itself. And so we have got at any rate a little more insight into the structure of the nucleus when we find that, in addition to the four protons, there are also two electrons. But that does not explain where their mass has gone, for we are landed with a nucleus heavier than it really is. The mass that we should get is 4·032, and the mass that we actually do find is 4. What has become of this mass? Some might be inclined to think that a little thing like that might easily be lost in the inaccuracies of experiment; but it is not so. These things have been determined by very many men, each keen to find all the others wrong and himself, of course, right; and the same conclusions have been reached in every case. Others, again, might say, Why worry about the difference between 4·032 and 4? If one ordered 4,032 tons of coal and found when it arrived that it was 4,000, perhaps one might be inclined to view the matter differently. It was just such a little difference as this that led to the discovery of the element argon, and, incidentally, to neon, crypton, and xenon, in the atmosphere.

The realization that there has been a disappearance of mass has resulted in giving us much wider conceptions of atomic structure. The old ideas that matter and energy were two different entities have now gone, and we regard matter as energy and energy as matter; and the modern theory of relativity led to precisely the same conclusion. What we call matter is but another form of what we call energy. They are one and the same, in different forms. Energy can assume many forms, some of which are heat energy, electrical energy, the energy of position, the energy of motion; and one is that which we are accustomed to call matter. When matter disappears, so does energy. But the energy that is used is the veriest trifle compared with what we know by several different channels of investigation and thought to be really there. The four protons in joining up by means (presumably) of the two nuclear electrons that are buried in them have lost mass—that is to say, have lost energy; but that energy has not been destroyed—it has been radiated from the place where the helium nucleus was formed to some other part of space. But, wherever it is, it has gone from the helium nucleus, and to put the condition of affairs back to what it was before the helium nucleus was formed—*i.e.*, the condition of four discreet and separate hydrogen nuclei or protons—it must be restored. Calculations show that it would require about two million million ergs of energy to effect this for a single gramme of helium. So that, while we know that the helium nucleus is in the ultimate made up of four protons and two electrons, yet to effect its separation into these constituents for so small an amount as a single gramme would require the introduction of eighteen million million feet-pounds of energy—an enormous amount. We see, therefore, that the nucleus of the helium atom—or what

is exactly the same thing, the alpha particle—is built in a very solid mould; and we have also seen that, besides being itself the nucleus of the helium atom, the alpha particle is a very important building-stone of the heavier atoms, as it is in their disruption that we first came across it.

It would be otherwise if we could cause four hydrogen atoms to unite and condense into one helium atom, and the accomplishment of such a feat for a few pounds weight of helium might solve many—possibly all—of the troubles of this wicked world.

Now, seeing that the differences between one element and another were to be found in the nuclear intensity and in the number of planetary electrons surrounding it, Rutherford set himself to see if by any means he could smash the nucleus of one element, and by so doing turn that element into one or more others. The old alchemists had similar dreams, inspired, I fear, by avarice, but they were a few centuries before their time. The differences between Rutherford and the alchemists were of such a fundamental character, and so obvious, that it might seem almost a discourtesy to him to refer to them; but there was mainly one that is of importance. The alchemists wished to change silver into gold, and it would certainly have been a very profitable industry had it been possible to do so at a reasonable cost. But they were trying to convert the lighter elements into heavier ones. Silver has a molecular weight of 108, whilst gold has a molecular weight of 197. Now, so far as the processes we see going on around us are any guide, this is the opposite of what nature wants to do. We see radium changing into radium emanation; but radium has an atomic weight of 226, and radium emanation one of 222, and the first becomes the second by the expulsion of an alpha particle. The expulsion of this alpha particle is a thing we have been unable to either accelerate or retard in the slightest measurable degree by any of the most drastic forms of treatment to which it has been subjected. The alchemists certainly had not the most remote conception of what they were up against, whereas in his efforts Sir Ernest Rutherford did know what the most likely conditions for success were. And it has always been a matter of surprise to me how straightly he went to the right ones. He was actuated by purely scientific considerations in his attack on the problem of the transmutation of the elements, and so long as he smashed up one element it was a matter of no commercial concern to him what the bits might turn out to be. And so for his attack he chose the element which seemed to promise the most chances of success, and that was nitrogen. Nitrogen has an atomic weight of 14 and an atomic number of 7. This means that in all there are fourteen protons in the nucleus, but that seven of them are associated with electrons, whilst seven others are free to exercise their influence on the seven planetary electrons which perform their orbital motions round the central nucleus of massiveness 14.

I have previously referred to what I described as the "mad rush" of an alpha particle from a radio-active atom through the atoms of the gas surrounding the radio-active substance, and to the straightness of its course, with an occasional very abrupt bend; and this track was described as the picture of the multitude of wounded atoms in the track of the alpha particle. And now it may be asked, What more did Rutherford want? Here were the atoms broken to pieces. Has this alpha particle not smashed them? Truly, in a sense it has, but not by any means in the sense that Rutherford was trying to break them. These are the pictures of the *wounded* atoms, not of the dead atoms. The alpha particle certainly goes through that part of space which the atom says is itself, and in doing so it knocks off one or

perhaps more of the planetary electrons. It does enough damage to make the atom feel very sick and lie down while its picture is being taken, but it soon recovers (perhaps in a thousandth of a second) and picks up one of the wandering electrons that are about, and is the same atom as it was before. Rutherford's object was to kill it past recovery, and to do that he must aim at the heart, the very centre of its being, the nucleus. And he did so aim, and his bullets were the alpha particles from radium C, that radio-active substance which is emitting alpha particles with the greatest vigour.

All through what I have been saying I have been trying to keep your thoughts off the infinite smallness (to man) of the atom and of all those things of which it is constructed, feeling that if you dwelt upon that side of the question you would confuse your minds by trying to picture to yourselves happenings in the realm of the infinitesimal, when you might just as well use the finite. But Rutherford's accomplishment is so wonderful that I would like to paint it as far as I can in its (to us) true colours. Imagine, then, the thing he was trying to smash—a tiny sphere, the core or nucleus of the nitrogen atom. The *whole* atom is only one hundred-millionth of a centimetre in diameter, and the core or nucleus of it is one hundred thousand times smaller than this. It is what we should call an infinitesimally small sphere, one ten-million-millionth of a centimetre in diameter. Rutherford shot at it with the alpha particles from radium C; that is to say, he placed a source of radium C near it. He had his own means of knowing when he hit it. There is no doubt he did hit it—not very often, perhaps; but he hit it once in about every thousand million shots, and when he did hit it he smashed it. The result of the smashing was that the bits of the core immediately picked up their proper numbers of planetary electrons—as, indeed, the alpha particle does—and they turned out then to be hydrogen atoms and helium atoms. It was truly an epoch-making accomplishment, this turning of nitrogen n o hydrogen and helium.

Since then the atoms of other elements have similarly been attacked at the heart and smashed, and, indeed, the old alchemistic idea of the transmutation of one element into two others has been effected; but not with the alchemistic object of turning the baser metals into gold (and so presumably making money), but with the purer and nobler motive of testing the theory of atomic structure and of seeing thereby what the ultimate building-stones of the atomic nucleus are. And so far as the results yet go it would seem that—as was expected—the fundamental entity in the core of all the eighty-seven with which we are acquainted is the proton; but these protons are very often combined in very stable groups of four, stuck together in some way as yet entirely unknown by the cementing effect of two electrons. This grouping, first of all, when it is broken up, gives rise to the alpha particle, which as soon as it has had time—a few millionths of a second—settles down into the helium atom. The protons not so combined become, when they are knocked out, hydrogen atoms.

What we would very much like to know about atomic structure is the form and condition of the planetary electrons, and how their orbits are connected together. In this matter, indeed, there is evidence enough already and to spare, if humanity was only clever enough to read it and unravel it. A great deal of progress has been made, but vastly more remains as yet not understood.

To bring some of this evidence before you may I again refer to my old simile of the solar system. Suppose we take a gaseous element like chlorine. Under ordinary circumstances chlorine does not, of course, give out any light, but in different ways it can be made to be luminous, either glowing

with a light that can be seen, or else glowing with a light which is too rapid in vibration to be visible light but which affects a photographic plate. Chlorine has an atomic number 17. It has, therefore. seventeen planetary electrons moving in orbits round its nucleus. These electrons, in their orbital revolutions, do not give out light, for if they did the gas, consisting as it does of atoms, would always emit a glow. Light can be excited in the gas, but it needs an exciting influence, such as Rontgen rays or an electrical discharge, through it to cause it to emit either visible or invisible light. What happens, therefore, when a gas is excited either by Rontgen rays or by way of the other means of causing it to glow? It was Bohr's great triumph to discover this, when he was a student under Sir Ernest Rutherford. He enunciated the theory that it was only when a planetary electron jumped in from one orbit that it was occupying to another that it could occupy that it emitted light. To make my meaning clear I think I had better deal with something bigger than atoms; and, as atoms and the solar system are all of a size to nature, it will make no practical difference. Corresponding, therefore, to the nucleus there is the sun, and corresponding to the electrons there are the planets—though leaving out the asteroids, or minor planets, the solar system, having only eight planets, is only about half as complicated as the chlorine system. Let us take one of the planets—say, Jupiter, sailing majestically along in its twelve-year orbit—and let something (a Rontgen ray, for example, or an electric discharge) cause it to become excited. There is no knowing what might happen. Jupiter might suddenly take it into its head to jump into the orbit of Mars, or even into the earth's. It would certainly be very interesting. But, strange as it may appear, and almost grotesque, perhaps, to the layman who is not acquainted with the evidence and experimental facts upon which such an assertion is based, we have the very strongest grounds for knowing that it is events such as this which, happening among the electrons of the chlorine atom, are the cause of the light which it emits. The evidence is quite overwhelming, and the realization that it is the jumping of the electron from orbit to orbit that gives rise to the light seen has enabled a considerable amount of knowledge to be gained as to the spacing of these orbits round the central core.

But first let me say that, unlike the planets in the solar system, the electrons cannot occupy any orbit they please. If Jupiter got displaced from its own orbit it might perhaps find a resting-place in some orbit, not at present occupied by any planet, between its own and that of Mars. There is no particular reason why it should come into Mars's orbit before beginning its ordinary doings again. But this is not so with the orbits of the planetary electrons in the atoms. Ther would be no resting-place, so to speak, for one of them if it got displaced from a position corresponding to Jupiter's orbit until it came to that of Mars, and, if it got displaced from that, no other until i came to that of the earth, and so on.

I have said that it is to Bohr that we owe this explanation, and the facts that gave rise to it are that it is found that when any gas (say, chlorine again) is made to be luminous, and the light is examined by means of a spectroscope, the light is found to consist of lines, and the wave-length of the various lines is quite a definite thing, capable of being measured with the very utmost refinement. The sets of lines corresponding to any of the more simple elements were found to be expressible by one or more very simple mathematical series. The lines in the spectra of the more complicated elements are also, no doubt, capable of being expressed in the same way, though in most cases the number of lines is

so great that it is a matter of the utmost difficulty to pick out the particular ones belonging to one series as apart from those belonging to another. The complete spectrum of hydrogen consists of at least fifty lines: how, then, can these all be due to the jumping of one poor electron from one orbit to another? The answer to this is that it does not need fifty electrons to occupy fifty orbits; the orbits may be there—and are there—though all but one of them are unoccupied. They are, shall we say, rings round the nucleus showing the places where the electron may rest, and between any two of them there is no position of peaceful revolution. It is not unlike a game of rounders, in which if a player leaves one base he must not stop until he reaches another, though, indeed, he may run over two or even three or four at a time. The particular wave-length of the light that is emitted depends—through what is known as Planck's quantum constant—on the difference of the energy-levels of the orbits at which the electron begins its jump and the one at which it stops.

From amongst the fifty lines comprising the complete hydrogen spectrum at least three series expressible by similar mathematical formulae are known These formulae differ only in the three series by numerical constants which indicate the different final resting orbits, which are for the three series the three innermost ones. The agreement between the wave-lengths calculated on this Bohr - Planck - Rutherford theory and those observed is so remarkable as to leave no shadow of doubt as to its general truth.

And so it will be seen that locked up in all the vast accumulations of measurements and knowledge which have been gathered regarding the wave-lengths of the spectral lines of the various elements there is a gold-mine of information concerning the orbits of the planetary electrons of those elements. But the sorting-out of this maze is a process which will require infinite patience, dogged determination, and great mathematical skill. The relatively few great mathematicians who have been engaged in it have taken us beyond the fringe of it, but only a little way beyond. They have unravelled the series of orbits for the hydrogen and helium atoms, but hardly more than that, and these are the two simplest, having only one and two electrons. What intricate complications there must be in an atom such as gold, with its seventy-nine electrons, and its at present incalculable number of possible orbits; or, to go further still, in the uranium atom, with its ninety-two! Celestial mechanics sink into insignificance in comparison with the problem of the atom

We have seen that all matter is built of two fundamental entities, electrons and prot ns. If you ask me what the electrons are made of, I can reply with some certainty that they are made of electricity—negative electricity, and nothing more. If you ask the same question about protons, I should say I am not quite so sure, but I think that they too are made of positive electricity, and nothing else. If you continue to press me and ask what positive and negative electricity are, I could only reply, "Those two things of which the universe in its material form is made."

But our journeyings into the infinitesimal have revealed universes of complexity in regions for ever beyond the reach of man's unaided vision. It is only by the use of the greatest faculty with which the Almighty has endowed mankind—the reasoning faculty—that penetration into these otherwise impenetrable depths has been possible. And we have found the same order and beauty in these realms of littleness as are to be seen in the more majestic regions of the visible.

WHEAT, FLOUR, AND BREAD.

With reference to certain Varieties of Wheat grown in New Zealand.*

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OF the world's crops perhaps none is more important as a foodstuff than wheat. Its cultivation dates back to prehistoric times, and in Persia, Greece, and Egypt it was one of the most valued cereals. The Chinese say that they cultivated wheat successfully twenty centuries B.C., which may or may not be true; but of the antiquity of wheat there can be no doubt.

Whatever were the first uses of the wheat-grain, it has taken precedence in historic times because more palatable and better bread may be made from it than from any other cereal. This is due to the gluten which it contains, a substance with peculiar chemical and physical properties. Rye is the only other grain which contains gluten and which may be treated in a similar way.

The cultivation of wheat is comparatively simple, and its adaptability to varying soil and climatic conditions is remarkable. It is grown in almost every country of the world, and is, among cultivated plants, almost unique in this respect. The world's great wheat-producing areas are situated in the temperate regions between the parallels of latitude 30° to 60° N. and 27° to 40° S. But wheat can be grown from the Equator to beyond the Arctic Circle. Its altitudinal range is also extreme. In England it is grown up to 600 ft.; in New Zealand it is often grown at 1,000 ft.; in Italy at 4,000 ft.; and in the tropics at 8,000–10,000 ft. Humboldt records its growth in Thibet at 15,000 ft.

Wheat is cultivated most successfully in countries where the winters are cold and the summers comparatively hot, as in Canada. For the most satisfactory growth and development of the grain, a cool, moist, growing season, followed by a bright, dry, and warm ripening-period of six to eight weeks, with a mean temperature of 18° to 19° C., is said to be the best. An annual rainfall of 20 in. to 30 in. is sufficient, so long as the greater part of it falls during the growing season. But in Australia some of the world's best wheat as regards quality is grown successfully where the annual fall is only 10 in. to 12 in. In Mesopotamia 5 in. is said to suffice.

It is not surprising, then, that the two or three wild species from which all present-day varieties are descended have given rise, by mutation, hybridization, and the effects of selection and cultivation under such widely differing environments, to an almost bewildering number of varieties. Thirty years ago the United States Department of Agriculture collected over a thousand different wheats without any difficulty; Percival, at Reading, is at present growing fifteen hundred distinct varieties; and there must be many not included in these collections. Many of these wheats are useless, for one reason or another, to the wheat-grower, but are kept by the cerealist only for the purposes of plant-selection and breeding.

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Amongst this large number, some wheats are naturally more valuable in certain countries and districts than others. Some yield well and some ill; some are rust-resistant and some are drought-resistant; some stand up to the wind and some do not; and some make good bread, and some scarcely make bread at all.

It is the work of the plant selector and breeder to separate the good from the not-quite-so-good; and to evolve new types, by cross-breeding, in which the required good properties are inherited from one generation to another. The plant-breeder may be materially helped, and much of his time saved, by the help of the analyst, who can say almost at once whether an old or a new wheat is better than its fellows. In practically every wheat-growing country of the world cerealists are at work trying to improve the standard of wheat varieties.

When one considers the different lines along which improvement may be made in the varieties now grown, it is found that there are four classes of the community to be considered, each with its own point of view; these classes are represented by the farmer, the miller, the baker, and the consumer.

If the farmer be asked what properties he prefers a wheat to possess, he will no doubt say that the best wheat is one which is disease-resistant and well suited to local climatic conditions, and which will give him a maximum yield per acre with the least expenditure in time and trouble. Briefly, one may say that the property of the wheat which is of most importance to the farmer is that of being produced in abundance. Quantity, not quality, is all-important; and, working along these lines, agricultural research has greatly increased the yield per acre of many wheat crops. A notable local example of this is the variety of College Hunters selected at Lincoln College, which yields on an average 4 bushels per acre more than ordinary commercial samples of Hunters wheat.

The miller, however, is not much concerned with the farmer's aspect of the case. What the miller wants is a variety of wheat which will yield flour in largest quantities per bushel; and which, moreover, will yield that flour easily. He requires, too, a wheat which will mill into a flour of good colour and quality (or strength), so that he may maintain a reasonably high standard in his product, month in and month out, and so satisfy the wants of his principal customer, the baker.

The baker likes a flour which will turn out a loaf light, attractive, well risen, and of good colour. He prefers a flour which will take up the greatest amount of water, thus enabling him to make the largest number of loaves from a given weight of flour.

Lastly, the consumer wants a loaf agreeable in appearance, palatable, nutritive, and digestible.

STRENGTH AND QUALITY.

The farmer aims, then, at maximum production in the cultivation of wheat. On the other hand, the miller, baker, and consumer want properties which on examination appear to be approximately one and the same thing; one may say that they are more particularly interested in the quality of wheat and wheat-flour.

Quality, which among millers is synonymous with "strength," is defined most satisfactorily and simply as follows: "A strong wheat is one which yields flour capable of making large, well-piled loaves."—(Biffen.)

The great virtue of a strong wheat is its capacity to yield flour producing a bread porous, bulky, and digestible. It is the search for

improved strength in wheats which is most characteristic of the recent work in the improvement of the world's wheat crops.

The question immediately arises as to how all-round improvement may be made on existing varieties. It may be said at once that the best wheat to mill, suiting farmer, miller, baker, and consumer, would be one producing the greatest quantity of flour of the best quality. It is easy enough to understand what is meant by "quantity" in this respect, and this is an important factor, for the amount of flour obtainable from different varieties ranges from about 66 to 76 per cent., though the average is about 72 per cent. The quality of flour, however, is harder to define.

Determination of Quality.

Commercially the quality of a wheat is often judged and the wheat bought by the appearance of the grain, its hardness, colour, plumpness, and freedom from seed impurities. These standards are, however, often unsatisfactory guides, and may even be misleading. A hard wheat, for instance, may be expected to give a stronger flour than a soft wheat, and this is true generally when judging two samples of the same variety; but it can be quite misleading when comparing two samples of different varieties—sometimes the softer wheat produces the better flour. It is also commonly supposed that a red wheat produces strong flour. This, again, is often true, but sometimes it is not. Nor, on the other hand, is paleness of the bran an indication of weakness.

Good weight per bushel is often considered by the grain-dealer to be an indication of strength. One does, of course, get more flour per bushel of wheat the heavier it is, but good weight is quite frequently no indication of strength.

Visual inspection, then, of wheat is at best an unsatisfactory method of determining its quality or real value.

Strength of Flour.

It has already been said that wheat-flour has the property, in common only with rye-flour, of forming a dough which may, on leavening, be baked into bread.

One knows the curious mass which remains when the starch is washed away from flour. This is the protein substance known as gluten, the isolation of which was first announced by the Italian Beccari in 1747; incidentally, this is the earliest case recorded of the isolation of a protein. It is due to this constituent that wheaten flour possesses the peculiarities so invaluable in the making of bread. The gluten, which is a cohesive and elastic substance, imprisons in small bubbles the gas generated by processes of fermentation, and it is upon the quantity and quality of the gluten that the strength of a flour very largely depends. If, then, the strength of a wheat and the flour made from it is dependent on the gluten it contains, it should be an easy matter to determine the amount of gluten present, and so obtain a measure of this property. Unfortunately, however, strength depends not only upon the quantity of the gluten present, but also upon its quality. It is the estimation of quality in gluten which presents difficulties.

One of the oldest methods, and still one of the best, for determining strength is to isolate the gluten by washing away the starch from the flour, and to judge its quality by its general appearance and behaviour—

that is, its cohesion, adhesion, colour, and elasticity. It is due to the elasticity and cohesiveness of the gluten that it retains in the dough the gas produced during panary fermentation: the more elasticity and cohesiveness it possesses the more the dough is able to expand and to rise, to take on the shape and appearance of a loaf, and to retain it when baked. The more the loaf rises, within reason, the better is the quality and quantity of the gluten; incidentally, it follows that the volume of a loaf may give one a measure of the quality of the flour from which it has been baked.

Having investigated the quality of the gluten, it is an easy matter to weigh the gluten in the wet condition, to dry it (which may take up to seventy-two hours at 100°), reweigh it, and so estimate its quantity.

METHODS OF DETERMINING STRENGTH.

In Italy, a method recommended very recently as a sure measure of the quality of a flour is simply to estimate the amount of water held by the wet gluten: the greater the amount of water the better is the quality of the gluten. On the other hand, at least one English authority (Armstrong) has considered that the less water a wet gluten contained the better should be its quality. It is, of course, possible that each method is correct for the wheats of each particular country, but the Italian method seems to have a certain application to New Zealand wheats.

Still another method of determining strength is to find the amount of water which a given amount of flour will take up in making a dough of a certain consistency. In New South Wales this method is found to be a definite measure of strength, and directly correlated with the volume of the loaf obtained on baking. This can readily be understood when one knows that Farrer based most of his cross-breeding of wheats on varieties possessing this characteristic to a marked degree; he used only those wheats possessing a good capacity for water, and it is natural that the descendants of these new Farrer wheats should be similarly characterized. This method, however, does not appear to have any application to local wheats.

Naturally, to the baker, a strong flour with a good capacity for water is of considerable value, for from a given weight he may make a larger weight of bread (that is, a greater number of loaves) than from a flour with a smaller capacity. Nor is the consumer at any disadvantage in this respect, for, though he is buying more water and less flour in his bread, it is a fact that a flour which absorbs more water in the making of a dough produces a loaf which is more palatable and more nutritious.

COMPOSITION OF WHEAT.

It is perhaps necessary to consider briefly the composition of the individual wheat-berry. The grain consists of three main parts—the germ, the endosperm, and the bran. The germ, forming about 2 per cent. of the berry, develops, under suitable conditions, into the plant; the endosperm, forming about 90 per cent. of the berry, consists mostly of starch, and in the development of the seed constitutes the food-supply of the germ in the early period of its growth; the bran, enclosing both germ and endosperm, consists of several complete coats, and protects the grain.

The art of the miller is to separate the endosperm, or flour-bag, as completely as possible from the bran. The endosperm forms nine-tenths of the wheat-berry; but in ordinary milling only about 70 per cent. of flour is obtained, the other 20 per cent. going to the bran or pollard fractions.

In so-called "whole-meal" flour very often only 85 per cent. of the berry is milled into flour; in "Graham flour" 100 per cent. of the berry is ground to the requisite fineness; but these terms seem to be used more or less indiscriminately.

In more detail, the composition by weight of the different parts of the grain is as follows: Pericarp, 3 per cent.; testa, 2 per cent.; germ (embryo), 2 per cent.; embryonic membrane, 3 per cent.; endosperm, 90 per cent.

The following table gives the average chemical composition of wheat according to different authorities (Kozmin, p. 47):—

——	Bell.	Richardson.	Hutchison.	Average.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Fat	1·48	2·30	1·7	1·8
Starch	63·71	67·88	71·2	70·0
Cellulose	3·03	1·90	2·2	2·0
Sugar	2·57	3·50	..	3·0
Protein insoluble in alcohol	10·70	7·45	11·0	10–12
Protein soluble in alcohol ..	4·83	3·58		
Mineral matter	1·60	1·84	1·9	1·8
Moisture	12·08	9·25	12·0	12·0

Ordinary white flour consists of—Starch, 70–75 per cent.; gluten, 8–15 per cent.; moisture, 10–15 per cent.; and smaller amounts of fat; sugar, 0·3 per cent.; cellulose, 0·2 to 0·3 per cent.; mineral matter, 0·5 per cent.

Starch, of course, is a source of heat or energy to the body, and the amount present in flour is important in this respect.

Gluten is a mixture of proteins; these are essential factors in the formation of muscle, bone, and all those parts of the body which have strength—in fact, all animal life seems to depend upon the transformation of proteid compounds. Proteins are therefore most valuable nutrients, and no others can replace them in their work of muscle-forming and body-building.

The small amount of mineral salts contains calcium, potash, soda, magnesia, and phosphorus, and furnishes the mineral matter necessary for the building of bone.

The germ is far richer in composition in protein, fat, and phosphorus than the rest of the grain, and is appreciably richer in vitamines.

CHEMICAL METHODS OF DETERMINING STRENGTH.

Many chemical and physical methods have been suggested for determining strength, but it cannot be said that any is infallible. The simple method of protein-estimation, when considered in connection with the quality of the crude gluten, is as useful as any. Protein-determination is approximately the determination of gluten by a chemical method as distinguished from the mechanical method of washing away the starch and weighing the resulting gluten.

When, in 1895, Osborne and Vorhees isolated five separate proteins from flour it was thought that the ratio of these substances present in the gluten might furnish a clue to strength. These proteins are—

	Percentage of Gluten.	
Glutenin	99·0	A glutelin. Insoluble in alcohol, water, or saline solutions.
Gliadin		A prolamine. Soluble in alcohol.
Edestin	0·6 to 0·7	A globulin. Soluble in saline solutions, insoluble in water.
Leucosin	0·3 to 0·4	An albumin, soluble in dilute acids.
	0·2 to 0·4	A proteose.

The proteins gliadin and glutenin constitute the bulk of the gluten; and it seemed that one might have only to determine the relative amounts of these two substances present in a flour for one to obtain a definite estimate of strength. But, after much research, Guthrie (N.S.W.) decided that strength depended upon the amount of glutenin, while in another part of the world Fleurent (France) decided that strength was dependent on the amount of gliadin present. A great deal of work has been done in Europe and America on this question, but the bulk of the evidence has suggested that strength is not dependent upon the relative amounts present of these two proteins. A year or two ago, however, the question was reopened by Martin, who showed that the older methods of separating these substances were faulty, and thus gave inaccurate results. Improved methods adopted by Martin have more nearly determined the real proportions of these constituents; and Martin has shown that, for a series of English wheats, the strength of the samples, as determined by actual baking tests, is closely correlated with the amount of true (amended) gliadin. Results obtained with local wheats, so far as they go, confirm these results.

It was observed twelve months ago in the Chemistry Section of the Department of Agriculture (N.Z.) that there was a rather remarkable connection between the ratio of crude gluten to calculated protein and the strength of the flour. More recent work confirms this relationship. A search of the literature on the subject does not reveal that this has been remarked by observers in other countries, and it is possible that a quick and reliable method for determining strength has been found. Since this method gives a numerical figure for strength, it is preferable to the method depending upon a physical examination of the quality of the isolated crude gluten and upon a verbal description which may vary with each individual worker.

BAKING TESTS.

It is quite probable that, as a check to the chemical tests just mentioned, it is necessary that a baking test be made under laboratory conditions; but where a large number of samples of a variety are examined any exceptions to the general rule that high protein content and size and texture of a loaf are highly correlated do not appreciably affect the average conclusions drawn, and baking tests may not be so necessary.

Bread is the product of cooking or baking a mixture of flour, water, and salt, which is made p rous by the action of yeast. There are many processes of breadmaking, of course, but for experimental purposes practically

only one or two are used. Perhaps the most satisfactory is the "straight dough" process, and for the following reasons: it requires less time, it is easier to control the temperature-changes over the comparatively short period of this method than over the longer periods of other methods, and the results are likely to be more accurate.

Reduced to simple terms, what happens in breadmaking is as follows: The dough is kneaded, and the ball of dough placed in a comparatively warm place; here the chemical action may be said to commence. The flour contains, as a rule, small amounts of sugar; and enzymes, always present in the flour, by converting some of the starch into sugar furnish a further and perhaps more important supply. The yeast ferments the sugar, carbon dioxide and alcohol being formed. Most of the alcohol escapes, while the carbon dioxide forms bubbles of gas, held by the gluten, and separated from each other by thin walls of gluten and more or less gelatinized starch.

To produce bread of good quality from the point of view of size and texture, the dough, or, in other words, the gluten, must be elastic—that is, it must be able to expand or rise. The volume of a loaf is a measure of this elasticity, and, it follows, of its quality. Having baked the loaf and measured its volume, other things, such as colour, &c., being equal, a practical measure of strength is obtained.

In making these tests it is essential, of course, that they are conducted so that the difference in the results are due to the inherent qualities of the flours themselves and not to modifications of the method used. The conditions under which tests are carried out must be strictly the same in every case, and these are maintained chiefly by very careful regulation of the temperatures, from the time the dough is first mixed to the time the bread is finally removed from the oven.

Really comparative tests are attained, then, only by exact control of all the processes and of temperature, no one flour being favoured more than another. A skilled baker no doubt adapts his methods to suit the different flours he uses, and by various modifications in kneading and fermenting improves a weak flour. But this does not prevent that flour from being essentially one of poor quality, not only from the point of breadmaking, but also from that of the extra time and labour necessary to remedy its defects.

CAUSE OF STRENGTH.

Having briefly considered the methods available for determining strength, it is interesting to examine the factors influencing strength or lack of strength in different varieties.

The effect of environment has received a considerable amount of attention, and in this connection the influence of soil and climate must be considered. Since nitrogen is an important constituent of gluten, it would appear that this essential plant-food might be an important factor in determining the quality of a wheat; but, as a matter of fact, the fertility of the soil has comparatively little to do with strength. It is true that fertility has almost everything to do with the yield of wheat per acre; but work at Rothamsted in England, and at Ontario in Canada, extending over twenty years, shows that it has little influence in the quality of the flour. That is not to say that an infertile soil will grow a good wheat, but that manuring an average soil does not appreciably improve strength.

ENVIRONMENT AND HEREDITY.

Undoubtedly the climatic conditions under which a wheat is grown have an important influence on its quality. It has long been realized that comparatively high temperatures during the day, long days, and absence of excessive moisture during ripening hasten maturation of the grain and increase its gluten content. Such conditions prevail in parts of Canada, Russia, and Australia, and in certain of the United States where some of the world's best wheat is grown. But it is worth noting that hot and dry Australia, which grows wheat of good quality, can also grow weak wheats. Hot and dry California grows more weak wheats than strong. England, which, on the other hand, has a climate more or less like ours, is replacing the soft wheats of a quarter of a century ago with relatively strong varieties which are competing successfully in open markets with the imported strong Canadian and States varieties. The point is, of course, that it is not absolutely necessary to have a comparatively hot and dry climate for the production of strong wheats, or that those climates can grow nothing but strong varieties. But for each environment there is one wheat which will probably be better, all round, than all others.

More important than environment is heredity. The variety of a wheat —that is, the strain from which it is descended—is all-important as a factor in determining strength.

The possession of strength may or may not be a Mendelian character, but it is a factor which may to a certain extent be controlled. The work which has been carried out in other countries is a constant reminder of this.

The plant-breeder, by selection, cross-breeding, and then by further selection, has been able to produce new wheats better adapted to their environment than older varieties. For instance, Biffen, in England, appears to have been very successful with the variety called Yeoman, which is reported to crop heavily on typical wheat-soils, and to possess strength sufficient for it to compete favourably with the strong imported wheats.

It is said, in some of the States, that wheats which were grown fifteen years ago and produced very good flour have been replaced almost entirely by still better varieties. Nearer home, the economic importance of the work of Farrer in Australia can hardly be overestimated. And here in New Zealand, College Hunters, selected at Lincoln College, has, because of its good yielding properties, displaced some of the varieties formerly grown in Canterbury.

It would seem an easy matter to introduce to this Dominion those varieties which have proved successful elsewhere. The trouble is, however, that a wheat which is good when grown in one country may deteriorate fairly rapidly when grown in another; or it may retain its strength but become such a poor yielder that it is unprofitable to grow. The complications are considerable, and it appears necessary for each country to work out its own problems in this respect.

WORK OF THE PLANT-BREEDER.

Any improvement in wheat and flour will be brought about mainly through the agency of the plant-breeder, who by selection or cross-breeding will raise the standard of existing varieties. This work is often very long and tedious, but the famous Marquis wheat of Canada and the States was discovered by accident at the Central Experiment Farm at Ottawa, and was not the result of years of work at all. Considerable time elapses between the crossing of two varieties and obtaining sufficient

grain to test practically in the mill and in the bakehouse. Here the analyst can be of material assistance in the selection of old and the production of new varieties. At a comparatively early stage he is able to report on the suitability or otherwise of a very small sample; even a few berries will suffice for a rough test. If an apparently promising new variety is found to yield a poor percentage of flour, or if it is lacking in strength, much time and labour is saved if that variety is discarded at the earliest possible moment and more promising material taken in hand. In the same way the analyst is able to report on the strength of varieties already well known, or being grown on a more or less experimental scale.

WHEAT IN NEW ZEALAND.

When the early colonists settled in New Zealand they probably brought with them the grain grown in the countries from which they had come. Whether these were the most suitable for local conditions is an open question, but it would appear that the wheats now grown in New Zealand are largely the descendants of the varieties planted by the early settlers; and one finds the survivors of half a century of cultivation to be largely the varieties called Hunters, Velvets, Pearls, and different Tuscans.

Samples of composite and representative soils of the countries of the South Island have been analysed and compared with soils from the famous wheat regions of Russia and Canada. The samples examined are average soils, and are not representative of any specially fertile areas; they have been found to compare favourably with the soils of these more famous wheat-growing countries.

Climate.

The climate of the wheat-growing areas of New Zealand is in general supposed to be equable and insular, there being no great contrasts of heat and cold. The average rainfall in these areas is about 25 in., an amount which is considered to be almost perfect for the maximum production of wheat. There are, of course, fairly wide variations from this average.

The winds which blow across Canterbury have had a considerable effect on the varieties now grown in that province. The notorious nor'-westers are fairly hot, dry winds by the time they traverse the Plains; this is to a certain extent an advantage, as it influences to a marked degree the character of the ripening of the grain. The great disadvantage, however, of these persistent winds is that they shake out very many varieties of wheat, and so reduce their yield. For this reason environment has had an important influence on the choice of varieties, for those wheats more or less immune from shaking out give less trouble and a greater return to the farmer.

It has been found that in many cases the Tuscan varieties are the most profitable to grow. They are prolific yielders, they can be used as spring wheats, and they are not threshed out by the wind to the extent that many other varieties are. The Tuscans are White-straw Tuscan, Purple-straw Tuscan, and Solid-straw Tuscan.

In many respects the average wheat grown in New Zealand is good. It yields exceedingly well, giving an average of over 30 bushels per acre, a figure which is exceeded nowhere outside western Europe: this yield is 100 per cent. higher than the United States average, and 50 per cent. higher than the Canadian. The crops are disease-resistant, and some of the varieties are peculiarly adapted to local climatic conditions. In appearance they are generally large, round, and rather bulky. All these

qualities are desirable, influencing considerably the variety favoured by the grower.

The fact remains, however, that, though the Dominion is a country specially favoured for the production of wheat, the varieties grown are lacking in some cases in strength. It is obvious that, so long as the farmer is paid for the quantity of wheat more than for its quality, any improvement in strength can come about only by the introduction of varieties combining good yield per acre with this other good property of strength.

WORK OF THE CHEMISTRY SECTION, DEPARTMENT OF AGRICULTURE.

Part of the work of the Chemistry Section of the Department of Agriculture is to examine the varieties now being grown, or which may eventually be grown, with a view to ascertaining what the possibilities are of improving the quality of the present-day wheats. Work was begun three years ago, and samples have been collected each season from the wheat-growing districts. A fairly wide range of varieties has been obtained; this includes a number of the wheats usually grown, as well as a considerable number of varieties grown more or less experimentally.

Samples of wheat of several pounds weight are received, and these are milled on an Allis Chalmers experimental reduction machine. This is really a small model flour-mill, and an effort is made to follow as closely as possible the processes carried out on a commercial scale. The model mill is, of course, not provided with any of the elaborate machinery characteristic of modern mills, and several of the processes, such as cleaning and scouring, have necessarily to be simplified. Duplicate results to within 0·2 per cent. can be obtained, and though, for obvious reasons, the actual milling figures may differ from those obtained commercially, it is considered that the ratios of flour obtained are strictly comparable.

Flour-milling may be described as the removal, as perfectly as possible, of the floury endosperm from the branny husk. The commerical miller does not simply mill each wheat as it arrives, since no single wheat may suit his requirements; moreover, reliable wheats may vary even from season to season. He judges his product largely by its strength, colour, and weight per bushel of wheat. The quality of the flour which he is marketing has constantly to be watched, and he endeavours to maintain a reasonable standard by blending, say, a strong wheat with another perhaps lacking in strength but possessing a good colour. The better qualities of different wheats are in this way incorporated into the finished product.

A striking feature of the modern flour-mill is the great care exercised in the cleaning of the grain preparatory to its actual milling. Impurities may consist of almost everything, from weed-seeds, earth, husks, straw, and ordinary dirt or dust down to iron nails. Most of these are removed by screening over sieves of different meshes. But, besides this method, wheat is often actually washed with water. This is effected by allowing the grain to fall through tall vessels in which streams of water flow; as the water descends the grain is scrubbed by a series of revolving brushes which remove all adhering earthy matter.

After cleaning, the wheat undergoes the process of "conditioning": this consists of the addition of water. The branny coating of the berry absorbs water more rapidly than the endosperm, and if the amount of water be suitably regulated it is possible to toughen the outer husk while leaving the kernel reasonably brittle, thus making the separation of flour from husk easier and more complete.

Cleaning and conditioning being satisfactorily carried out, the grain is now ready for actual milling. The gradual breaking and shearing of the wheat-berry is brought about by several series of rollers so mounted that the distances between their surfaces may be adjusted. These rollers are fluted, and revolve so that the surfaces between which the berry is nipped travel in the same direction. One roller revolves at about 350 revolutions per minute, the other at about two-fifths of that rate. The grain of wheat falls between these rollers, is nipped between them and more or less torn apart. This operation is known as a "break," and its object is to break or tear the grain with the least possible friction. As a result the miller obtains a mixture of coarse particles of kernel (to many of which the coarse particles of husk still adhere), a small quantity of bran, and a small quantity of fine flour.

Separation is brought about by two methods. The mixture of material, known as "stock," is screened on sieves of varying sizes, ranging from those made of wire with about sixteen meshes to the linear inch down to screens made of silk so finely woven that they contain 120 meshes to the inch. These sieves are shaken mechanically, the finely divided particles of flour falling through the meshes and the larger particles remaining on the screens. The larger particles are partly heavy pieces of broken kernel and partly pieces of torn husk. To separate these a current of air is so adjusted that it blows away the lighter branny fraction without disturbing the heavier pieces of kernel. Thus by a combination of sifting and air-blowing the stock is further separated into a small quantity of flour, a small quantity of finished husk or bran, and a larger quantity of large particles of kernel still contaminated with husk.

These coarse particles, called "semolina," are now passed through a second pair of break-rolls more finely fluted and set closer together. Their object is to rip off more kernel from the husk; the resulting stock is treated as before, by sifting and air-currents, and more flour and more finished bran obtained. The coarse particles still remaining are subjected to further breaks, with finer adjustments, until no more flour may be safely removed from the adhering husk or bran. As soon after each operation as any flour is obtained it is removed; this prevents contamination, in grinding, with finely divided husk, which darkens the colour of the flour and so reduces its quality.

The intermediate particles of semolina in each operation are sent to the reduction-rolls—smooth rolls with no fluting, set closer together than the break-rolls, and which revolve at more nearly the same rate. Here the size of the particles is still further reduced, and finely divided flour produced, together with the usual mixture of coarser particles contaminated with much adhering bran. Purification is repeated as previously described, and the process of reduction repeated until a sufficiently good grade of flour can no longer be separated. "Flour" consists of all that portion of the grain which passes a 120 silk sieve; it is more or less conventional milling practice to call all that portion of the disintegrated and purified particles which separate on the sixteen-wire sieve "bran" and all the intermediate portion, consisting of low-quality flour and the smaller particles of finely divided husk, "pollard." Pollard and bran together constitute the "offals"; in other countries the different offal fractions go by many names, such as "shorts," "sharps," "midds," "middlings," &c.

On account of the nutritive value of the germ, its fate in the process of roller milling is interesting. According to millers, the presence of the germ in the finished flour is liable to cause the latter to become sour, and then

imparts to it a disagreeable taste and odour. They therefore do not hesitate to remove it as completely as possible. This is easily carried out, for so much fat is present in the germ that it is not ground to the fineness of flour, but is flattened into discs, which may be readily separated on the silk sieves: this affords an easy way in which part of the germ may be separated. It is commonly believed that the whole of the germ is removed, but it is more probable that less than two-thirds of it is lost in this way; the remainder probably remains with the flour.

Modern milling, then, aims not at pulverizing the grain into a mass of torn husks, endosperm, and vegetable tissue, as in the old days of grinding between stones, but at separating them in a series of steps, breaking down the berry slowly, and, at each operation, sifting away the freed particles of the endosperm (or flour-bag) before despatching the opened grains to the next roll for further treatment. This goes on until nothing but the bran skins remain, the greater part of the interior having been removed.

Such, in brief, is a description of the principles of milling. In actual practice the process is a good deal more complicated, and it not infrequently happens that the wheat-berry may be subject to 120 distinct operations before it has yielded its maximum of good marketable flour.

EXPERIMENTAL MILLING.

The following comments on the value and limitations of experimental milling are taken from Bulletin 1187, *Experimental Milling and Bakign*, U.S. Department of Agriculture, Washington, 1924; they have no doubt been arrived at as the result of the experience gained in the most comprehensive scheme yet undertaken in the experimental milling of flours, and are on that account interesting and authoritative:—

"Experimental milling, although not entirely comparable with commercial milling, gives results which indicate as truly the relative milling-value of different wheats as tests made on a commercial mill. Because of the small quantity of wheat, small expense, and short time required for making tests in the experimental mill, it is more practicable than a commercial mill for use in determining the relative milling and baking value of different wheats. Experimental milling tests are also particularly important in determining the milling properties and strength of small samples obtained from wheat-breeding experiments.

"The operation of an experimental mill necessarily differs in some respects from that of a commercial mill. There is, for instance, no continuous or automatic flow of stock from one machine to another, as in a commercial mill. This is an advantage, as it gives the operator a better opportunity to vary his method of grinding and bolting to suit the character and condition of the individual sample. Other points of difference are the absence of [cleaning apparatus] purifiers, and bran and shorts dusters. In spite of these differences an experienced operator is able to accomplish results on an experimental flour-mill which compare favourably in quality and efficiency with the work of commercial mills."

NEW ZEALAND VARIETIES.

On an average it has been found that the flour-milling properties of New Zealand wheats are very fair; they give from 66 to 76 per cent. of flour on milling, the average being about 72 per cent. It takes just as much power and labour to produce flour from a poor milling-wheat as from a good one, and naturally it is in the interests of all concerned if those varieties of wheats

which are producing an amount of flour below the average can be eliminated and in their place the better varieties grown. This should be possible by the adaptation of special wheats to special localities, though much data must first be collected as to the all-round properties of each particular variety.

TESTS FOR STRENGTH.

All those tests which have already been outlined have been applied to the flour obtained from local wheats; for routine work it is considered that determination of the following are useful and necessary: Ash, moisture, wet gluten, dry gluten, ratio of wet to dry gluten, protein, and absorption of water. In addition, baking tests are carried out when possible.

The amount of ash tells much about the quality and the grade of a flour; the higher the ash, the darker the colour and the lower its grade. Different grades of flour are characterized by a fairly definite ash content, viz. :—

	Ash Percentage.
90-per-cent. patent flour	0·42–0·48
95-per-cent. patent flour	0·45–0·48
Straight patent flour	0·48–0·54
Straight grade flour	0·54–0·61
First clear flour	0·61–0·66
Second clear flour	0·66–0·75
Low-grade flour	0·75–0·90

The more moisture a flour carries the less will be the amount of water which it will absorb when it is made into dough. A good flour should not exceed about 13 per cent. of water, as any amount above this may produce injury to the flour by giving moulds and bacteria a chance to grow.

An important test is the determination of wet and dry gluten. For the baker, of course, the best flour is one which shows good uniform gluten content from week to week, enabling him to maintain a good average in his baked product without any change in his methods. From an examination of the gluten content, both as to its quality and quantity, one may get the best single guide to the strength of a flour, its behaviour on fermentation, and the loaf which may be baked from it. A good flour will be one containing from 11 to 12 per cent. of dry gluten and 33 to 36 per cent. of wet gluten.

The water-absorption figure gives a good idea of the amount of bread that may be made from a given weight of flour. It also serves as a guide to the amount of water necessary to add to the dough in the baking of experimental loaves.

Baking tests, being practical tests, are undoubtedly of value, any appreciable difference in quality being at once apparent in the baked loaf. There is no doubt that, with New Zealand wheats, high gluten content is generally associated with good loaf volume. But where baking tests are carried out over a number of weeks, and on days of which some are colder than others, exact control of all conditions is difficult. The yeast may vary in quality; it is, moreover, very sensitive to small temperature-changes. This makes it a difficult matter to get absolutely concordant results, though good approximations are possible. It is doubtful, then, if actual baking tests give more accurate information for a large series than the usual laboratory analyses, though many investigators have considered that baking tests alone provide reliable evidence as to the quality of a flour. It is interesting to learn that one of the biggest bakeries in the world, a company which annually produces 400,000,000 lb. of bread, considers that chemical

analysis of every sample of flour received from every mill is an absolute necessity.

As to results with New Zealand flours, the following table summarizes the averages of the results obtained from the varieties more usually grown :—

Variety.	Average Gluten Content per Cent.	Number of Years harvested.	Number of Samples tested.
Velvet	11·7	3	16
Solid-straw Tuscan	11·4	3	13
College Hunters	9·8	2	8
White-straw Tuscan	9·6	3	13
Pearl	9·4	3	10
Purple-straw Tuscan	9·3	1	5
Victor	8·4	3	8
Dreadnought	12·5	2	4

The well-known local variety Velvet may undoubtedly be classified as a medium-strong wheat. Velvet is a somewhat low yielder, and apt to thresh out where exposed to the wind; but all the results obtained so far show it to be generally the best-quality wheat grown in its district. Its average yield of flour per bushel of wheat is above the average, and its capacity for water remarkably good.

A number of varieties not usually grown have been examined, and, though often represented by single samples, are interesting as being wheats which give promise of good strength; they do not appear to have deteriorated, as is often the case, in their new surroundings. They are as follows: Burbank's Super, Thew, Huron, Marquis, John Brown, Rymer, Essex Conqueror, Jumbuck, Zealand, Queen Fan, Red Fife, Red Straw, Queen Fair, Turretfield Eclipse, Hybrid W. Other samples which have been tested are Yeoman (a strong new English variety), Bordier, Ceres White, Emperor White, Eclipse Red, Little Joss, Major, Mark Lane, Marshall's No. 3, New Standard Red, Prohi White Winter, Perfection, and Snowdrop.

A majority of these miscellaneous samples was grown at the Ashburton Experimental Farm, and in one season at least contained an amount of gluten much above the average. Whether this is due to the varieties themselves, or to the growing season experienced, or whether it is owing to the environment in which these wheats were grown, only the testing of further samples from future harvests will show.

One of the samples of outstanding merit is Burbank's Super, a wheat grown at Flaxton, Canterbury. In this one district at least this variety compares favourably with other wheats in yield per acre; it is also said to mature early. This particular sample has had the high protein content of 14·44 per cent. A variety cannot, of course, be judged by one or two samples, but this wheat shows the possibilities of adaptation of new strong varieties to local conditions.

Marquis, the famous Canadian variety, hardly maintains the high level reached in the country of its origin, but it still remains a wheat well above the average. Huron, another Canadian wheat, might be regarded as a strong wheat.

Samples of Thew and Rymer, two Farrer crosses, may be considered good-quality wheats.

Dreadnought, a variety grown in North Otago, yields a good percentage of flour containing a good amount of gluten; it is a medium-strong wheat when grown in that region. Some soils in the Waitaki County (Weston) are said to be particularly adapted to the growing of Dreadnought, and average yields of 40 to 50 bushels per acre are reported. This variety is said by some millers to be unsuitable for milling; by others it is used in large quantities. This may be due to differences in the variety when grown in different environments, but all samples tested in the experimental mill have behaved quite satisfactorily, and the resultant flour has been above the average in strength.

Essex Conqueror is not generally regarded as a particularly strong wheat, but it is worthy of note that it was amongst the strongest Ashburton wheats received from two different harvests. Red Fife is a strong wheat, at one time grown extensively in Canada, where it is considered to be one of the best wheats for breadmaking. This variety has been used largely in cross-breeding experiments. Marquis is said to be a cross between an Indian wheat and Red Fife. Yeoman is another wheat with Red Fife as one of its immediate ancestors. Several samples of Yeoman do not appear to be better in quality than the average wheat grown in the Dominion, but samples grown in different seasons and in different localities are required for testing in order to ascertain the suitability of new varieties such as Yeoman to local conditions.

VARIETY OF WHEAT AND STRENGTH.

The data so far obtained show that the variety of wheat grown has an important effect on the strength of flour. A descendant of a stong variety proves, on an average, to produce a strong flour. Some varieties maintain a relatively high standard under varying conditions; such a one is Velvet. Others show a fairly large range of gluten content, but the average for the variety may often be low. This being the case, such a variety must be regarded as lacking in strength.

CLIMATE AND STRENGTH.

The effect of climate on strength has already been mentioned, and with samples collected in New Zealand it has been found already that some districts show to distinct advantage. The drier districts in general produce strong wheats, and this is very apparent in the samples collected from the notably arid district of Central Otago. Of nine samples collected from the drier parts of Tuapeka and the Upper Taieri, both of which districts abut on Central Otago, five have been found to be strong and four medium-strong wheats. There are probably other districts in the Dominion with characteristic climates which will also prove to be especially adapted to the growing of strong wheat.

Though no one variety may be found to possess combined the desired good characteristics of disease-resistance, high yield per acre, gluten content, flour-yield, weight per bushel, and the required milling-qualities, it is possible that, by experimental milling and chemical investigation, evidence will eventually be obtained indicating which varieties combine most of these qualities and are therefore the most profitable to grow and use for selection.

The results so far obtained go to show that varieties of good strength are already being grown. The possibilities of improvement are considerable,

not only in the wheats already widely known, but also in those now being experimented with, and which may ultimately be adopted on a large scale.

ACKNOWLEDGMENTS.

The writer wishes to express his thanks to Mr. B. C. Aston, Chief Chemist, Department of Agriculture, New Zealand, who inaugurated the testing of New Zealand wheats, for permission to publish the results summarized in the above paper, and also for his interest and help during the present investigations; also to Mr. F. T. Leighton for his help and advice, especially in the actual experimental milling.

MOULDS ON FROZEN MEATS.

By F. T. BROOKS, Botany School, Cambridge, England.

IN a paper by Mr. A. M. Wright which appeared in the *New Zealand Journal of Science and Technology* for December, 1923, it is stated that "black-spot" of cold-store meat may be caused not only by *Cladosporium herbarum* but also by *Mucor mucedo* and by *Penicillium glaucum*. On the other hand, Brooks and Kidd, and Brooks and Hansford, found in their researches on mould contaminations of meat that "black-spot" was due exclusively to *Cladosporium herbarum* (*Special Reports 6 and 17*, Food Investigation Board, Department of Scientific and Industrial Research, London). In view of this discrepancy, two of Wright's experiments of which details are given by him have been repeated in the Low Temperature Research Station at Cambridge, the results of which invalidate Wright's contention that "black-spot" of meat may be caused by other fungi than *Cladosporium herbarum*. Thus mutton was inoculated with the spores of *Mucor mucedo* and kept at a temperature of —1° C. until growth was well established, after which the meat was kept at a temperature of —11° C. for four and a half months. Upon examination after this period there was found no trace of "black-spot" upon the meat, but only the typical growth of *Mucor*. Similarly, mutton inoculated with a species of *Penicillium* and kept at 4° C. until the fungus was well developed showed no trace of "black-spot" after being kept for four and a half months at —11° C.; again only the typical growth of *Penicillium* was present.

If Wright's contention that "black-spot" may be due also to *Mucor* and *Penicillium* be true, one wonders what is the cause of the black colour of such spots, for the hyphae of both *Mucor and Penicillium* are colourless. On the other hand, Brooks and Kidd have shown that in all the "black spots" examined by them the colour was caused by the dark hyphae of *Cladosporium herbarum*.

Wright states also that *Mucor mucedo*, a *Rhizopus*, and *Penicillium glaucum* were often isolated from "black-spots." This is not surprising, seeing that these moulds are often superimposed upon meat contaminated by *Cladosporium herbarum*. Under such conditions special precautions must be taken to isolate *Cladosporium herbarum*, as this fungus grows slightly deeper in the tissues than the other moulds.

PETROLIFEROUS AREAS OF NEW ZEALAND.

By P. G. MORGAN, M.A., F.N.Z.Inst., Director of the Geological Survey, Wellington, New Zealand.

THE older sedimentary rocks of New Zealand (Palaeozoic, Triassic, and Jurassic) are in general too metamorphosed to contain oil, except such as may have been introduced from younger strata. This opinion is confirmed by the "carbon ratio" wherever it is ascertainable. On the other hand, the Cretaceous (more especially the Upper Cretaceous) and the Tertiary strata are usually not much altered, and in many localities contain at least traces of petroleum. The areas occupied by Cretaceous and Tertiary formations, exclusive of igneous rocks associated with them, and by Quaternary sediments, beneath which Tertiary strata do or may occur, are shown in the following table :—

	North Island.	South Island.	Total.
	Sq. m.	Sq. m.	Sq. m.
Post-Tertiary strata	7,151	11,481	18,632
Tertiary strata	15,304	4,231	19,535
Cretaceous strata	5,117	557	5,674
Totals	27,572	16,269	43,841

This table shows that probably two-fifths of New Zealand contains strata that may possibly yield mineral oil, and the thorough prospecting of those portions which afford indications of petroleum appears to be justifiable.

Seepages of oil have been observed in the following localities : Dobson and Liverpool State Coal-mine, near Greymouth ; Kotuku, in North Westland (east of Greymouth) ; Warwick River Valley and Mangles River, in central Nelson ; Cheviot district, in south-east Nelson ; Ure River and near Ward, in Marlborough ; Paraparaumu, north of Wellington (in peat) ; near New Plymouth ; at various localities between Gisborne and East Cape ; Waiotapu, twenty miles south of Rotorua ; Whangarei district (?) ; and perhaps elsewhere. Emanations of inflammable gas, and other supposed indications of oil, such as brine springs, have been observed over very large areas, more particularly that lying east of the Tararua–Rimutaka–Ruahine–Raukumara Range, which extends from Wellington north-eastward to near Cape Runaway.

In three districts the indications of petroleum are unusually strong. These are (1) North Westland, (2) New Plymouth and adjoining areas, (3) Gisborne – East Cape district. A few sentences will be devoted to each of these, and some of the other localities will be briefly discussed.

(1.) NORTH WESTLAND.

The strongest indications of petroleum occur at Kotuku, which is twenty-one miles by rail east of Greymouth, near Lake Brunner. Here over an area of several acres the surface gravels are heavily impregnated with oil, and considerable quantities can easily be collected by digging holes. One shallow bore is said to have produced 14,000 gallons (English)

of oil, most of which was lost; and several hundred barrels have been obtained from other shallow bores, and a shaft sunk in the Pleistocene sands, gravels, and clays underlying the surface gravels. Below these beds come Middle Tertiary (Oamaruian) mudstone and limestone. Beneath the limestone are some marly and sandy beds, probably Oamaruian, underlain by a conglomerate, which in turn rests on Palaeozoic argillites and greywackes. The structure is obscure, but there appears to be a gentle anticline in the Tertiary rocks, slightly complicated by faulting. A good many bores have been drilled into the Tertiary strata, but the results have not been satisfactory. Several bores, on entering the limestone, struck salt water and carbon dioxide in large quantity, but obtained nothing better than "shows" of oil, which in one or two cases are stated to have continued until the Palaeozoic rocks, which, owing to their metamorphic character, are hopeless as a source of oil, were entered.

The oil produced at Kotuku was of good quality, with a paraffin base, and such as one would expect to be associated with a considerable body of petroleum. Unfavourable features are the widespread cover of fluviatile and glacial gravels, almost everywhere hiding the Tertiary strata, and the somewhat limited extent of the possible oil-producing area. The north part of this lies between the Southern Alps and the coastal Paparoa Range, and the southern part extends as a narrow belt between the Southern Alps and the sea at least as far south as Ross.

There are localities other than Kotuku in this comparatively long strip which offer possibilities to the oil-seeker. At Fireball Creek, near Kumara, the limestone along an anticlinal axis (Brunner anticline) has a petrolaceous smell. Not only the structure but other conditions are here favourable for the accumulation of oil.

(2.) NEW PLYMOUTH AND ADJOINING AREAS.

Oil films were observed on the sea near the Sugarloaves, New Plymouth, by the Maoris long before the advent of Europeans. Oil-prospecting operations have been carried on at intervals since 1866. Numerous wells have been drilled, and many of these yielded a little oil. In 1905 a bore, afterwards known as the Birthday Well, struck oil in some quantity; and a few years later several bores drilled by Taranaki Oil-wells, and one drilled by the Blenheim Company, for short or even long periods began to yield oil. These bores were all between New Plymouth and its port to the west, at the Breakwater. At the present time there is still a small production. The writer has no exact data, but believes that the total oil-production at New Plymouth is between 1,500,000 and 2,000,000 English gallons, or, say, 40,000 to 50,000 barrels. Most of this oil came from a depth of a little over 2,000 ft.; some from over 3,000 ft. The oil was associated with a large amount of inflammable gas, deadened by a considerable proportion of carbon dioxide, and a moderate amount of salt water. It comes from Pliocene strata, overlain by 250 ft. or more of volcanic agglomerate and tufa, so that the structure is obscured. So far as can be ascertained from an examination of the bore-logs and general considerations, the dips are gentle. Volcanic rocks rising through the Pliocene sediments and the volcanic agglomerate form the conspicuous steep-sided hill of Paritutu and the neighbouring islands known as the Sugarloaves. A paper by Dr. T. H. Easterfield, which was read before the Pan-Pacific Congress in September, 1923, shows that the oil so far produced at New Plymouth has probably been affected by volcanic heat. It is of

good quality, with a paraffin base, which perhaps indicates a vegetal origin.

One bore at New Plymouth, the Blenheim, has been drilled to a depth of well over a mile (5,726 ft.) in Upper Tertiary strata. Although at a depth of about 2,200 ft. this well produced an appreciable amount of oil, no flow was encountered at deeper levels. Its lower portion, however, passed through a great thickness of brown claystone or shale, which was slightly petrolaceous, showing on analysis something like $\frac{1}{5}$ per cent. of petroleum.

Wells have been drilled a few miles south of New Plymouth, some miles to the north-east, and again at Inglewood and Huiroa, which are places well inland to the south-eastward. Only light shows of oil were encountered. Even the deepest of these wells, the Huiroa, with a total depth of 4,921 ft., probably has its bottom in Pliocene rocks. These are presumably underlain by several thousand feet of Miocene strata.

Lately Mr. F. G. Clapp, an oil geologist of the highest repute, has reported favourably on the prospects of oil in Taranaki, and Taranaki Oil-wells (Limited), a company with headquarters at Melbourne, but possessing the name of a former New Zealand company, is about to bore at a point a mile and a half north-west of Tarata (ten miles east of Inglewood), where a moderately favourable structure has been found.

(3.) GISBORNE–EAST CAPE DISTRICT.

Indications of oil in the Gisborne–East Cape district are plentiful, and a considerable amount of boring has been done (1) at Whatatutu and other localities within twenty miles or so of Gisborne, and (2) in the Rotokautuku Block, Waiapu Valley, far to the north. A few barrels of oil, mostly of a light character, have been obtained. The oil seems to come from Upper Cretaceous beds, which are much crumpled and faulted. These are overlain unconformably by Tertiary strata, ranging in age from Eocene to Pliocene, which are probably not folded to any extent, but are broken into tilted blocks by important faults usually striking either east-north-east or south of east.

Recent work by the Geological Survey shows that the Upper Cretaceous shales, sandstones, and limestones of the northern part of the Gisborne–East Cape district are petroliferous over considerable areas. Although these rocks present very irregular structures, the geologists who have done the field-work believe that the area has possibilities. They are, in fact, hopeful that one or more oil-pools exist.

(4.) OTHER LOCALITIES.

At Chertsey, a few miles north of Ashburton, Canterbury, a wild-cat bore was drilled a few years ago to a depth of 2,170 ft. This bore penetrated 500 ft. or 600 ft. of the Recent and Late Pleistocene gravels forming the Canterbury Plain: it may then have entered Late Tertiary gravels, sands, and clays. From a depth of 1,368 ft. downward these strata yielded a little petroleum in the form of black very viscid globules, and a little inflammable gas. The oil and gas were probably derived from buried vegetal matter.

At Tane, north-east of Eketahuna, east Wellington, a bore has been drilled to a depth of 3,000 ft. through Late Tertiary claystones. This yielded traces of oil and gas. At Waipatiki, near Weber, east of Dannevirke, some distance to the north, two wells have been drilled to

considerable depths, through Tertiary sediments, principally calcareous claystones. The deeper well encountered some gas, and at a depth of 1,140 ft. or thereabouts there was a light show of oil from a greensand layer. The writer also saw a faint, somewhat doubtful "show" at the other well.

At Waiotapu, twenty miles south of Rotorua, a little amber-coloured oil reaches the surface of a small sinter terrace near the ordinary water-level of the Waiotapu Stream. It rises with a little hot water and some non-inflammable gas. The heat of the water causes the more volatile portion of the oil to evaporate, and a small ring of pitchy material appears round each little pool. This oil appears to owe its origin to the distillation of carbonized wood buried in the underlying pumiceous tuffs.

Various other New Zealand oil-occurrences, though economically unimportant, are of an interesting character, but need not here be described. As indicated in the previous paragraphs, the North Westland, New Plymouth, and Gisborne–East Cape districts possess possibilities, and all deserve further investigation. Blind stabbing or wild-catting is most inadvisable, and further prospecting should be carried out only by concerns or persons with large capital, employing experienced geologists and drillers.

PRELIMINARY ACCOUNT OF THE GEOLOGY OF CHATHAM ISLANDS.*

By R. S. ALLAN, M.Sc., Otago University.

DURING January and February of 1924 an expedition to the Chatham Islands was organized by the Otago Institute. Most branches of natural science were represented, and it is hoped that the results of this research will soon be available to scientific workers in Australasia. In the field I was associated with Dr. J. Marwick, of the New Zealand Geological Survey, who was concerned with the palaeontology. I have to thank Dr. Marwick for permission to include here some of the most important of his results.

The Chatham Islands, which form part of the Dominion of New Zealand, lie some 500 miles to the east of Christchurch. They were discovered by Lieutenant Broughton in 1791. The largest member of the group—Chatham Island—is about 350 square miles in area, but some 70 square miles go to form a huge lagoon, Te Whanga. Pitt Island comes next in size, with an area of 20 square miles. It lies to the south of the main island, from which it is separated by the 14 miles of ocean forming Pitt Strait. Mangere and South-east Islands are sufficiently large to graze sheep, but the remainder of the group are rocky islets, tenanted by sea-fowl.

Apparently the first scientist to investigate the geology of the Chathams was Dieffenbach, in 1840. His papers are not available here. Von Haast (1868) and Hector (1869) both published notes on rock-specimens which had been sent to them from the Chathams by other workers, notably H. H. Travers, C. Traill, and Percy Smith. Hector (1895) visited these islands,

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* This paper, in a slightly modified form, was read at the Adelaide meeting of the Australasian Association for the Advancement of Science, in September, 1924.

but his stay was very brief. Dieseldorff (1901 and 1902) gives the most comprehensive report that has yet appeared. His conclusions are drawn from material collected by Schauinsland in 1896–97. His petrographical work especially is most helpful. Cockayne (1901) gives valuable details of physiography and climate. Forbes, Milne-Edwards, Andrews, and others have dealt at some length with the very interesting remains of extinct birds of the Pleistocene strata. Park (1910) and Marshall (1911) both summarize the available data.

Little need be said at present of the physiography and structure of the group. The islands are for the most part low-lying and covered by swamp or low bush. The northern parts average about 200 ft. above sea-level, and are flat or gently undulating, while exposures of rock are usually restricted to the shore-line. The southern block is a broken plateau reaching to nearly 1,000 ft. above sea-level. It is bush-clad, and its rugged surface makes geological investigation somewhat difficult. The south coast is a magnificent line of steep cliffs, ranging from 600 ft. to 700 ft. in height, and having a linear extent of 14 miles. These form a very fine natural section.

The Chathams owe their present form to a combination of two factors: the formation in the Pleistocene or late Pliocene of a series of faulted blocks, which have been depressed or elevated to different levels, and the subsequent erosion and linking-up of more or less isolated blocks by immense sand-bars and spits. The largest of these has a length of some 27 miles, and cuts off an extensive arm of the sea to convert it into a brackish lagoon 70 square miles in area.

The oldest rocks present are quartz-mica schists, exposed only in the north of the main island, but no doubt forming the undermass of the whole group.

Exceptionally there are north-easterly, meridional, or even north-north-westerly strikes apparently in regions of local dislocation. In the North-west Peninsula the schists have a very regular east-west strike, and are folded into a series of short-limbed anticlines and synclines, with a uniform dip of 30° either to the north or to the south. In the north-east area, while the strike is as above, the beds are tilted at high angles, ranging from 45° to 80°, to the north.

The average strike of the schists is approximately east and west. Professor Park has previously speculated on the possible relation between New Zealand and the Chatham Islands, suggesting that the Chatham Island schists represent the eastern arm of a great synclinal area, the western side of which is found in Central Otago and the Southern Alps. This hypothesis receives no support from the present investigation.

The schists may be correlated on lithological grounds with the schists of Central Otago; and, if the views of Dr. Marshall and Dr. Benson be accepted, they may range from late Palaeozoic to early Mesozoic in age, though the Geological Survey prefers to consider them older Palaeozoic. During the Cretaceous and early Tertiary periods the area seems to have been a land-mass undergoing extensive peneplanation, for the schists are overlain with great unconformity by Tertiary limestones and tuffs, which Dr. Marwick places in the Oligocene. In the North-west Peninsula the old peneplain surface is exposed as an extensive "fossil-plain" of great regularity, tilted slightly to the north.

The oldest Tertiary beds are a series of bryozoan limestones, which vary greatly in composition, colour, and hardness. They have been classed as

Palaeozoic by Haast, and as Senonian by Dieseldorff. However, they contain a few Brachiopoda which are undoubtedly of Tertiary age.

With the limestone are associated a considerable thickness of volcanic tuffs and tufaceous limestones varying greatly in appearance. The exact relation of these beds to the bryozoan limestone is not yet clear—they are probably younger; in one section, however, the limestone overlies the tuffs, but the junction seems to be a thrust-plane. Flows and dykes of limburgite are common in this formation. The tuffs yield a fairly rich harvest of Brachiopoda and Mollusca.

Dr. Marwick has identified fifty-one species of Mollusca, and of these only one is still living. He states,* "The very low percentage of 2 (Recent forms) can surely be taken to indicate a position well down in the Tertiary —say, Upper Oligocene. . . . Of the fifty-one species only two occur in New Zealand, [but] most of the genera have been common in New Zealand

[*W. Martin, photo.*

FIG. 1.—Quartz-mica schists near Waikawa, Chatham Islands. Looking west along the strike.

since the Waiarekan, and some of the species have close relatives in our Tertiary strata. The general specific resemblances favour Hutchinsonian or Awamoan age, though a few have definite Wanganuian affinities."

A fine new species of the genus *Pleurotomaria*, rare in Tertiary rocks, is a most interesting find. Another noteworthy species which occurs in great abundance at one locality is *Gryphaea tarda* Hutton—a shell not found in New Zealand, but one which has been recorded from the Patagonian beds of South America, and from the Balcombian and Janjukian of Australia.

The only remaining sedimentary rocks (except superficial deposits) are some shallow-water sands and grits which lie unconformably on the bryozoan limestone. These beds were discovered and investigated by Dr. Marwick. They contain abundant fossils in a good state of preservation, but the number of species is limited. Dr. Marwick finds but thirty-five species of Mollusca, of which twenty-two are lamellibranchs and thirteen gasteropods. "Twenty of the thirty-five are Recent species, a percentage of 63. This percentage suggests correlation with the Nukumaruian or

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* Quotations from Dr. Marwick as taken, with his permission, from a paper entitled "The Palaeontology of the Chatham Islands," read before the Otago Institute on the 8th July, 1924.

Middle stage of the Wanganui series, although some of the characteristic species of that stage are missing. On the European scale the approximate age is Middle Pliocene."

The most interesting feature of the palaeontology of the Chatham Islands appears when a comparison is made with New Zealand.

In the Oligocene 4 per cent. of the molluscan fauna are identical, but in the Pliocene the common species make up 63 per cent. of the forms. It is evident that a means of communication non-existent in the Oligocene had become established by the mid-Pliocene. The nature of this communication is far from clear.

Dr. J. Allan Thomson is at present examining the brachiopods, and in a preliminary note to the writer he states that they show a close generic relationship with New Zealand forms, but are for the most part specifically distinct.

[*W. Martin, photo.*

FIG. 2.—Columnar basalt intrusive into the schist, Mopihanga Creek, Chatham Islands. The wave-cut surface indicates a local uplift of 15 ft.

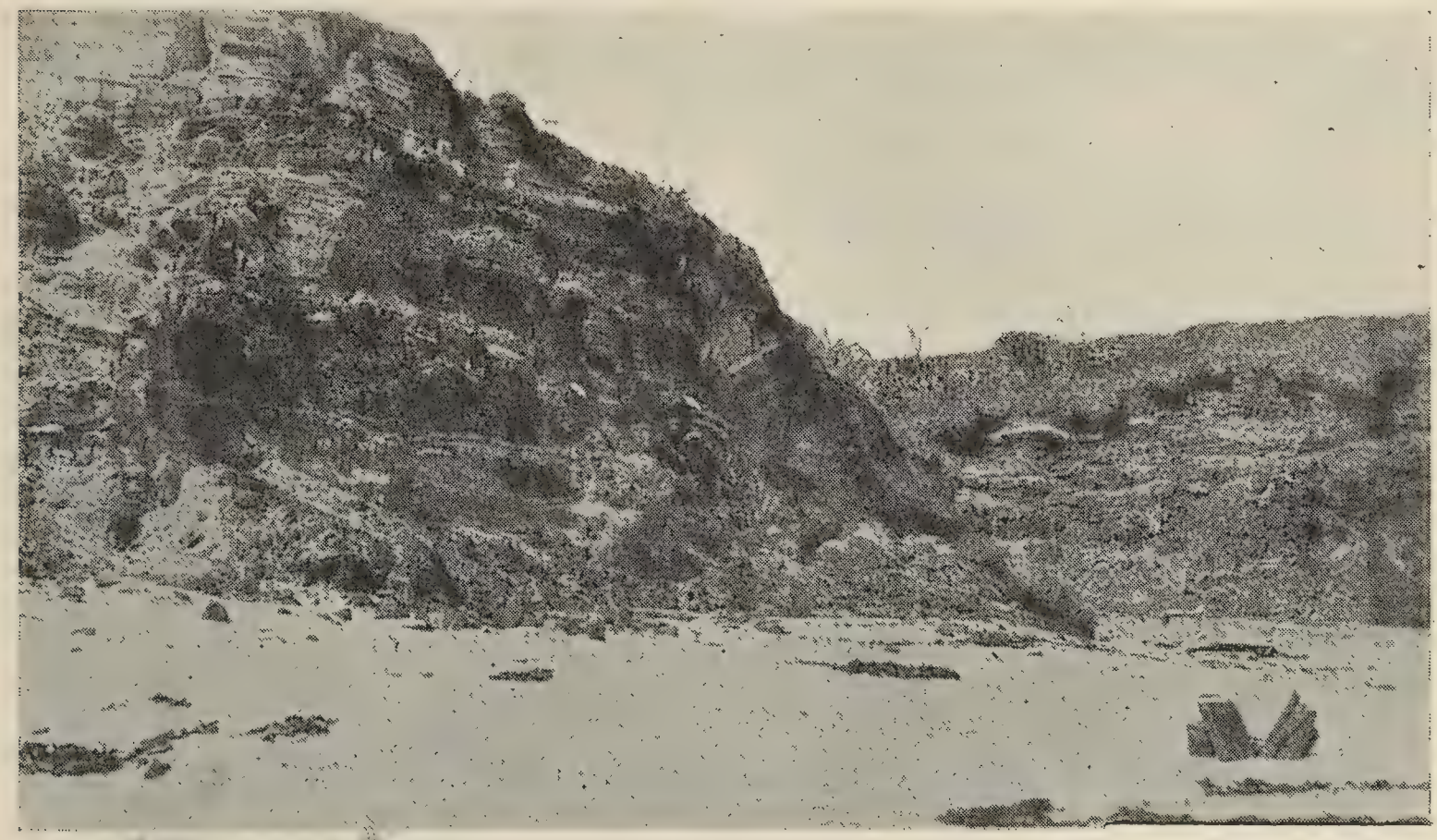
The volcanic rocks of the Chatham Islands proved to be of special interest. They are of wide distribution, making up more than half the surface outcrop of the main island and almost the whole of Pitt Island and the other smaller islets. Owing to lack of time the volcanic rocks were not exhaustively studied, and much remains to be done before the field relationships of the various types can be worked out in detail. However, it seems clear that at least two distinct periods of volcanic eruption can be distinguished. The earlier consists solely of limburgites (magma basalts of Dieseldorff) and allied tuffs. Individual flows have a thickness of from 30 ft. to 40 ft. or more. Dykes up to 15 ft. wide were noted. The majority of these lavas seem to have been intruded into loosely consolidated tuff on the sea-floor. The associated tuffs are at least 500 ft. in thickness. This series, which is restricted to the northern part of the main island, may be placed definitely in the Oligocene period, since tuffs containing a fauna of this age are intercalated.

The second series cannot be accurately dated, but is probably post-Oligocene and pre-Pleistocene. A phonolite of this series is intrusive into

a tufaceous limestone of Oligocene age, while these rocks generally have been involved in the Pleistocene fault-movements. These rocks, which are mainly basaltic in composition, make up almost the whole of the southern half of the island and most of Pitt Island as well.

In the southern cliffs of the main island 600 ft. to 700 ft. of horizontal flows and interbedded tuffs are exposed in vertical section, and it is probable that this series is at least 1,000 ft. in thickness.

Since the writer's examination of these rocks is still incomplete and Dieseldorff's papers are not everywhere available, it is considered advisable to enumerate the types he recognized. In 1901 he noted the following:



[*W. Martin, photo.*

FIG. 3.—Pleistocene peat deposit, Whangatete Bay, Chatham Islands. The cliff is some 40 ft. in height.

Mica-bearing andesite (SiO_2), 60·42 per cent.; slaggy, fine-grained, coarse-grained, and hornblende-bearing basalts; mica-bearing basalt (SiO_2), 48·3 per cent.; and ophitic olivine basalt. In 1902 he gave a petrographical description of three types—viz., feldspar-basalt, mica-bearing feldspar basalt, and nepheline basalt.

To these the present investigation adds some extremely interesting alkaline lavas, including a trachytoid phonolite and a sodalite phonolite. A further noteworthy addition is an olivine-gabbro found as a xenolith in a basaltic tuff. The olivine phenocrysts show a beautifully developed corona-structure. A trachyte containing fragments of sanidinite was found as an isolated boulder.

This exceedingly interesting region was but very superficially explored, and further investigation will probably lead to the discovery of other rock-types. It is the intention of the writer to continue this research during the early part of 1925.

Finally, it may not be out of place to record my warm appreciation and thanks for the wonderful hospitality and kindness which I received during my two months' sojourn at the Chatham Islands.

I have to thank Mr. W. Martin, B.Sc., for permission to use the photographs which accompany this report.

SOUNDINGS IN THE SEAS AROUND NEW ZEALAND.*

By H. T. FERRAR, M.A., F.G.S.

THE interpretation of the geological results obtained by the recent scientific expedition to the Chatham Islands raises the question of the relationship of this elevation of the sea-bottom to the New Zealand elevation. The occurrence of a mid-Tertiary mollusc—namely, *Gryphae tarda* Hutton—in the rocks of South America, Australia, and the Chatham Islands, together with its absence from New Zealand, has led Dr. Marwick to suggest that the Chatham Islands may lie upon a distinct Pacific arc lying beyond the New Zealand continental platform. At his request I have prepared this paper. I have also to thank Mr. P. G. Morgan for pointing out that Dana† was before Suess in directing attention to dominating trend-lines in the Pacific. Dana mentions the Chatham Islands–Campbell Island island chain, and states that the N. 40° E. trend line of New Zealand is continued to the south, through the Auckland and Macquarie Islands, to 58° S. These and other reasons prompted me to inquire what foundation of fact underlay certain bathymetrical maps which have been published lately.

The charts published by the Admiralty give nearly every sounding that has been made. In the present connection see charts of the Pacific Ocean, of the South Pacific Ocean, and of Macquarie Island and other outlying islands. The sketch-map which accompanies this article was partly traced from the South Pacific Ocean chart in order to show the distribution of soundings and the depths obtained in the seas around New Zealand. Some submarine contours have been added.

In the seas to the north-east, north, and north-west of the North Island soundings are numerous—in fact, more numerous than shown here, for the sketch-map merely indicates their density. To the east of the North Island few soundings have been made far out from the coast, and the deepest one is on a steep slope which may descend to greater depths, perhaps into a southerly extension of the Kermadec Deep. There are no soundings over the place of the east-coast earthquake-origins of Hogben's map.‡

To the west of the North Island the numerous soundings show that the sea-floor is very uneven; to the west of the South Island there is a large area free from soundings.

To the east of the South Island there are many shallow soundings close to the coast, a few have been made between these and a line joining the Chatham Islands to Campbell Island, and very few to the eastward of this line. All the soundings between the outlying islands of New Zealand and the coast of the South Island are less than 1,000 fathoms, except one of 3,450 fathoms shown on Gregory's map,§ about half-way between the South Island and the Chatham Islands, which Mar hall|| states to be a clerical error. South of the Chatham Islands the sea deepens quickly, apparently to about 2,800 fathoms, which is about the average depth of the South Pacific Ocean.

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* Read at a meeting of the Geological Section of the Wellington Philosophical Society on the 13th August, 1924.

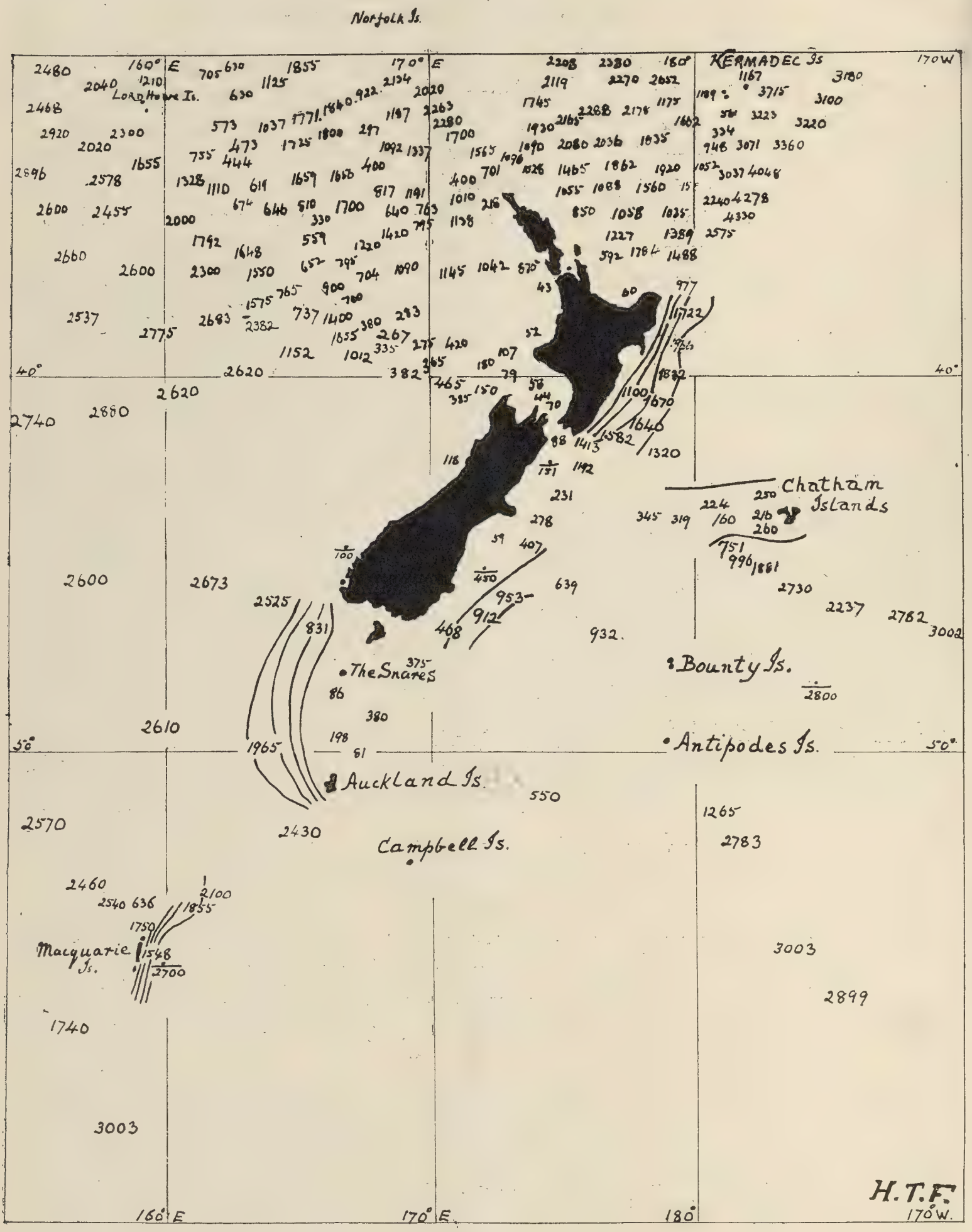
† J. D. DANA, *Manual of Geology*, 4th ed., p. 39 [1895]. See also *U.S. Exploring Expedition, 1838–42*, p. 16 *et seq.*, 1849.

‡ J. HOGBEN, *Trans. N.Z. Inst.*, vol. 50, p. 281, 1918.

§ J. W. GREGORY, *Australasia*, vol. 1, map facing p. 1 (Edward Stanford), 1907.

|| P. MARSHALL, *Aust. Assoc. Adv. Sci.*, 1909, vol. 12, p. 435, 1910.

To the south-east of the South Island the soundings are not sufficiently close to allow submarine contours to be drawn with safety. A single sounding of 550 fathoms between Antipodes Island and Campbell Island seems to show that Dana's island range exists as such.



Sketch-map showing the distribution of soundings and some of the depths obtained in the seas around New Zealand. The figures are placed approximately over the spot where the sounding was made, and give the depth in fathoms.

To the south the New Zealand N. 40° E. line continues as a ridge south-westwards beyond the Auckland Islands, but how far beyond is not yet known. The ridge does not connect with Macquarie Island, as Dana stated was the case, nor is there any evidence that the Macquarie Island ridge continues as far south as 58° S. Soundings show that the Macquarie Island ridge is short and descends steeply on the east to unknown depths. It is

of interest to note that Macquarie Island is rising or is being tilted towards the west, while the Auckland Islands have been depressed or have been tilted towards the east. Also, the basalts of the former are more altered and appear to be much older than those of the latter.*

The following questions, which are of more than scientific interest, arise: Does the Kermadec Deep extend southwards past the east-coast earthquake centre and cut off the Chatham Islands from New Zealand? The two soundings of over 900 fathoms to the east of Port Chalmers lend colour to this view. What happens to the east-west submarine contours at the Chatham Islands? The dominant strike of the schists of these islands is east-west. Are the Chatham, Bounty, Antipodes, and Campbell Islands on a ridge or on the edge of a submarine platform? Speight† places the continental scarp only thirty miles away from the east coast of the South Island. Does water 3,000 fathoms deep separate Ross Dependency from New Zealand? Bathymetrical maps indicate a connecting "rise," but any soundings that have been made seem to belie this.

It is obvious that more soundings are necessary before these questions can be answered, and it is suggested that the recently invented sonic sounder could be utilized for this purpose at very small cost. In a chart of the Californian coast published by the United States Hydrographic Office in 1923 it is stated that approximately five thousand soundings were taken in thirty-eight days' sailing at a speed of 12 knots, the area of sea-bottom contoured being 34,000 square miles.

OCCURRENCE OF THE LEATHERY TURTLE IN NEW ZEALAND.

By W. R. B. OLIVER, F.Z.S.

THE leathery turtle, or luth (*Dermochelys coriacea*), is such a rare visitor to our shores that its occurrence is always worthy of record. I am aware of its appearance on the New Zealand coast on four occasions only. Two of these have been placed on record by Mr. T. F. Cheeseman; two additional occurrences are here recorded. The four New Zealand occurrences are as follows: (1.) Cape Brett, May, 1892. (2.) Between Bay of Islands and Mangonui, 1894. (3.) New Plymouth, February, 1895. (4.) Doubtless Bay, February, 1924: discovered by Messrs. J. Matthews and R. C. Cross.

The leathery turtle is distinguished by the peculiar structure of the shell, or carapace, which, unlike that of other living species of turtles and tortoises, is not fused with the vertebrae and ribs. Furthermore, the carapace, or shell, consists of numerous small polygonal plates covered with a leathery skin. There are twelve longitudinal ridges on the body—five dorsal, two lateral, and five ventral.

The true home of the leathery turtle is the tropical and warm temperate seas, but it is not common anywhere. Stragglers have been recorded in England, France, Victoria, and New Zealand.

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* H. T. FERRAR and G. T. PRIOR, *Nat. Ant. Exp., 1901–4*, vol. 1, Geology, pp. 96, 97, and 109, 1907.

† R. SPEIGHT, *Trans. N.Z. Inst.*, vol. 40, p. 41, 1908.

PRIMITIVE WINGLESS INSECTS.

PART II: THE ORDERS PROTURA AND COLLEMBOLA.

By R. J. TILLYARD, M.A., Sc.D. (Cantab.), D.Sc. (Sydney), F.N.Z.Inst., F.L.S., F.E.S., C.M.Z.S.; Entomologist and Chief of the Biological Department, Cawthron Institute, Nelson, N.Z.

ORDER PROTURA.

THE minute insects comprised in this order were unknown to science until the year 1907, when Professor Silvestri erected the new order for a species sent to him from West Africa. In the following year another Italian entomologist, Professor Berlèse, described further species discovered in Italy, and since then they have been found in England and in North America. Professor Berlèse arbitrarily changed Silvestri's ordinal name "Protura" to "Myrientomata," and suggested that these new forms of animal life were not really insects, but repesentatives of a new class lying between Myriapoda and Insecta.

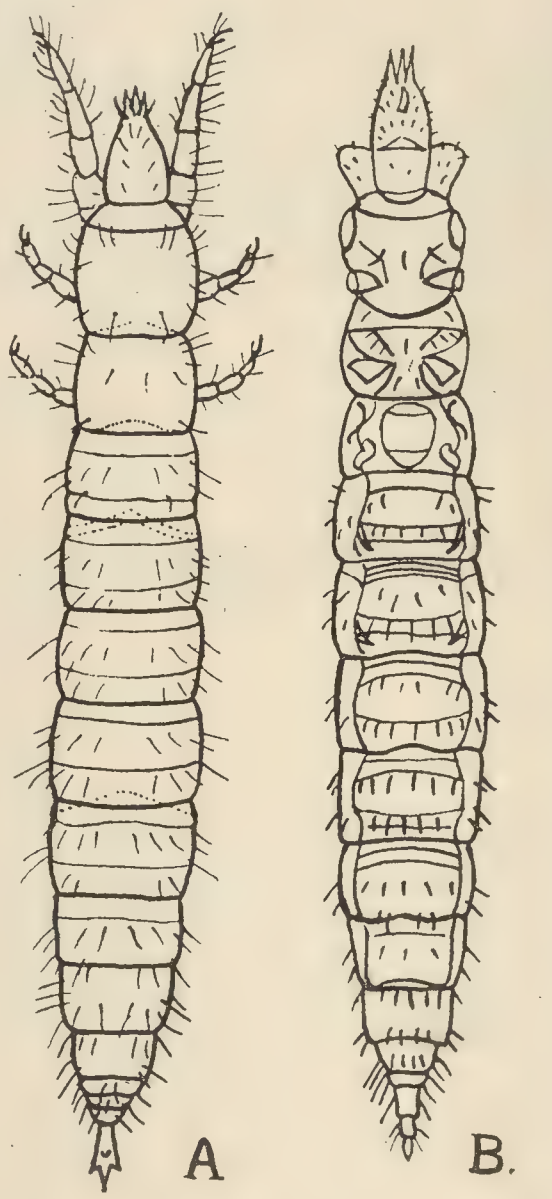

FIG. 11.—*Acerentomum guineense* Silvestri. Order Protura, family Acerentomidae. Length, 1·2 mm. A, dorsal, B, ventral view, the latter with legs omitted.

The general trend of modern opinion is that these little animals are truly insects of a very ancient type, though some authorities still follow Berlèse. The chief argument against their being insects is the complete absence of antennae. In other respects, notably in the form of the mouth-parts, the separation of the body into three distinct regions (head, thorax, and abdomen), the restriction of the walking-legs to three pairs situated on the thoracic segments, the position of the genital organs, and the segmentation of the abdomen, the Protura are true insects. Fig. 11 shows the dorsal and ventral views of one of these tiny insects, whose total length is little over 1 mm. The following points should be noted:—

The *head* is small and somewhat pear-shaped, and possesses neither antennae, compound eyes, nor ocelli. The mouth-parts are small and withdrawn into the head-capsule, but form a very efficient sucking-beak; the elongate labrum forms the upper and the similar labium the lower portion of this beak, while the slender lancet-like mandibles and maxillae slide to and fro between them; both maxillary and labial palpi are present, the former having four, the latter three segments.

The *thorax* has a short prothorax with moderately long legs attached; meso- and meta-thorax are larger segments, with shorter legs; the tarsi have only one segment, ending in a single claw.

The *abdomen* is peculiar in being formed of twelve segments, which is the highest number known in the Insecta, though actually never more than ten are completely formed, the two terminal ones being at most vestigial and often absent. In the Protura the first eight abdominal segments are well formed, the last four very small. The first three segments carry ventral appendages, or styles, similar to those found in Thysanura; of these, the first pair is the largest, as is also the case in the Campodeidae (see Part I). The external genital organs are placed behind segment 11.

It will easily be seen that many of the characters of this order are adaptations to a life passed in the soil. Such are the elongate, cylindrical form, the small head pointed in front, the absence of organs of vision, and the shortness of the legs. In many terrestrial insect larvae the antennae are greatly reduced; hence it is possible that their entire absence in the Protura may be due to this same cause, the palps perhaps sufficing for the sensation of touch at the head end.

There seems every reason to believe that species of this order must exist in the natural, uncultivated soils of Australia and New Zealand. The insects are most difficult to find, as they are so small and delicate that even careful turning over of samples of soil is likely to crush them. They are most likely to be found in a natural soil fairly rich in humus, either from the forest-floor or from a peaty locality. Examined with a hand-lens they appear as minute whitish, semi-transparent creatures, something like tiny elongate mites. They should be picked up on the tip of a slightly moistened camel's-hair brush, and transferred to a small tube containing 70 per cent. alcohol. Possibly some slightly larger forms may be discovered here, as the apterous fauna of Australia and New Zealand contains many of the largest species known to exist in the world.

ORDER COLLEMBOLA (Springtails).

This order contains the most highly specialized of all known primitive wingless insects, easily distinguished from all other groups by the fact that, both in the adult stage and in the embryo, no more than six segments can be seen in the abdomen. Some authors consider this fact of such importance that they have not hesitated to make a separate class for them. We think this is going too far. Any group which satisfies the accepted definition of the class Insecta ought to be retained within it, notwithstanding a marked reduction in the number of abdominal segments, which, to our mind, is of no greater importance than the loss of wings or legs, or a reduction in the number of segments of the tarsi. Definitions of classes should be kept as simple as possible, and that accepted for the Insecta is surely as clear and simple as any in the realm of zoology. If the animal is an arthropod—*i.e.*, an invertebrate animal with a segmented body and segmented appendages—and, in addition, has the body divided into head, thorax, and abdomen, then it belongs to the class Insecta. Judged by this simple definition, both the Protura and Collembola are undoubtedly orders of insects.

The popular name of "springtails" has been given to the Collembola on account of an outstanding character possessed by most, but by no means all, of them. This is the presence of a *spring*, or saltatory organ, attached ventrally to the fourth or fifth segment of the abdomen. This organ is undoubtedly formed by the fusion of two originally separate abdominal appendages; these must have had three distinct segments, of which the first have fused together to form the *manubrium* (Lat. = handle) shown in fig. 13, A. The second pair of segments remain separate, and are called

the *dentes* (*dn*); they spring close together from the manubrium, and are generally more or less elongate and curved. At the end of each dens is a tiny claw-like segment called the *mucro* (fig. 13, D). The dens is frequently provided with a crenulated margin and delicately feathered hairs.

It is generally stated that the spring is held in position by means of a small catch situated ventrally on the third abdominal segment, the idea being that this catch holds the two dentes stretched close below the body, and, when liberated, allows them to spring backward with great force, so that the insect is projected sharply forward. Against this explanation may be placed the fact that the so-called "catch" is a very small organ when present, and that it is absent from a large number of species which have the spring very well developed. It seems just as reasonable to suppose that the spring is placed in its forward taut position by muscular action, or that it is helped to keep in that position either by the action of the hind legs or the *ventral tube* (fig. 13, A, *vt*). This latter is an appendage of the first abdominal segment, either simple or bilobed; at its free end it carries a pair of eversible sacs, which exude a sticky substance. Its chief function is believed to be that of enabling the insect to adhere to smooth objects. The ventral tube is sometimes called the *collophore* (Greek = glue-carrier); in it we can recognize the homologue of the enlarged first pair of abdominal appendages found in Protura and Campodeidae.

Some other features of these insects call for special comment. The mouth-parts are retracted within the head, and are of the typical mandibulate type, except that the palpi are obsolete, being represented only by setae. The antennae usually consist of only four segments (rarely six), but the distal one may be long and annulated. True compound eyes are absent, but are replaced by a set of separate eye-elements (fig. 13, B), often situated on a pigmented patch, and evidently representing a reduced stage of the original organ. Some species carry, between the eye-elements and the base of the antennae, a pair of minute *post-antennal organs;* these are sense-organs of unknown function, but with a nerve-supply derived from the optic ganglion.

The legs are well developed, but the tarsi have only a single segment; this ends in a well-developed claw (fig. 13, C, *cl*) and a smaller process called the *embolium (em)* or *unguiculus*. An interesting feature of the tarsi in some species is the presence of a long specialized hair ending in a sucking-disc and known as a *tenent-hair* (fig. 13, C, *tn*); its function is evidently to enable the insect to hold on to a smooth surface.

Springtails are abundant everywhere, some species even being found on the snows of the Arctic and Antarctic regions. They are mostly found on the ground, in debris, moss, or leaves, sometimes in rotten wood, or under moss and logs. A few species live on the surface of still water, and may occur in countless swarms. Little is known of their life-history, except that the larval stages differ but little from the adult. They seem to be exceptionally abundant during the winter and early spring months, but can be taken at any time during the year. They are not easy to catch; some collectors use a glass tube, which they try to place over the insect before it jumps; others dab at them with a moistened camel's-hair brush; others, again, adopt the heroic expedient of overwhelming them with 70 per cent. alcohol thrown over them from a tube, and then pick them up with a fine camel's-hair brush. Having tried all three ways, I can only say that they are all alike in this: that they provide plenty of sport, an excellent training for the eye, and, generally, not much reward for hard work.

Very little indeed is known about the Collembola of New Zealand or Australia, and there must be a large number of species awaiting discovery. It is with the hope of stimulating interest in the order that the following short account of the classification is given, with information about the known New Zealand species.

The order is a fairly extensive one, and is divided into two well-marked suborders, as follows :—

Body elongated, with subcylindrical abdomen having its tergites either free or only partially fused together; tracheal system nearly always absent	Suborder ARTHROPLEONA.
Body short, with globular abdomen formed of fused segments; tracheal system present	Suborder SYMPHYPLEONA.

SUBORDER ARTHROPLEONA.

This suborder contains two very distinct families, as follows :—

Prothorax well developed, with distinct pronotum; cuticle generally granulated; spring either absent, or else attached to fourth segment of abdomen	Fam. 1. PODURIDAE.
Prothorax poorly developed, without pronotum, the mesonotum covering it completely above, cuticle smooth; spring present, attached to fitfh abdominal segment	Fam. 2. ENTOMOBRYIDAE.

Family 1. PODURIDAE. (Fig. 12.)

In this family the post-antennal organ is usually present in the form of a minute rosette; the spring is present in the subfamily Podurinae, absent in the subfamily Anourinae (or Aphorurinae). The former are

FIG. 12.—*Anoura spinosa* Lubbock. Order Collembola, family Poduridae. Length, 10 mm. Lateral view. (Drawn by A. Tonnoir.)

mostly minute insects, some living in moss and moist earth, others on the surface of still water. The almost world-wide little blue-black species *Achorutes viaticus* Tullberg has been found commonly on Macquarie Island by Mr. Harold Hamilton, of the Dominion Museum; it must surely also occur in many parts of New Zealand. *Triacanthella alba* Carpenter is a tiny white species discovered on Auckland Island. Two small species have been described from ants' nests in New Zealand—viz., *Lipura incerta* Moniez, and *Drepanura brachycephala* Moniez.

In the subfamily Anourinae, New Zealand and Tasmania share between them the distinction of possessing the giants of the whole order in the three fine species of *Anoura*, found hiding in moss or under stones and logs. The New Zealand species is *A. spinosa* Lubbock (fig. 12),

distinguished by being covered all over with fleshy spines. When young it is a delicate blue-green or olive-green, with yellowish spines; when mature it becomes a dull slaty grey. It is a broad insect, very sluggish, with very short legs, and grows to a length of nearly $\frac{1}{2}$ in.

Family 2. ENTOMOBRYIDAE. (Fig. 13.)

This family is dominant throughout the world, though not a single species has yet been described from New Zealand. Quite a number of species belonging to it may be found by sorting debris from the forest-floor or by examining rotten wood. Several subfamilies are recognized, distinguished by the presence or absence of the post-antennal organ and by the comparative lengths of the first four abdominal segments. To illustrate the family, we have to select the only species known from the

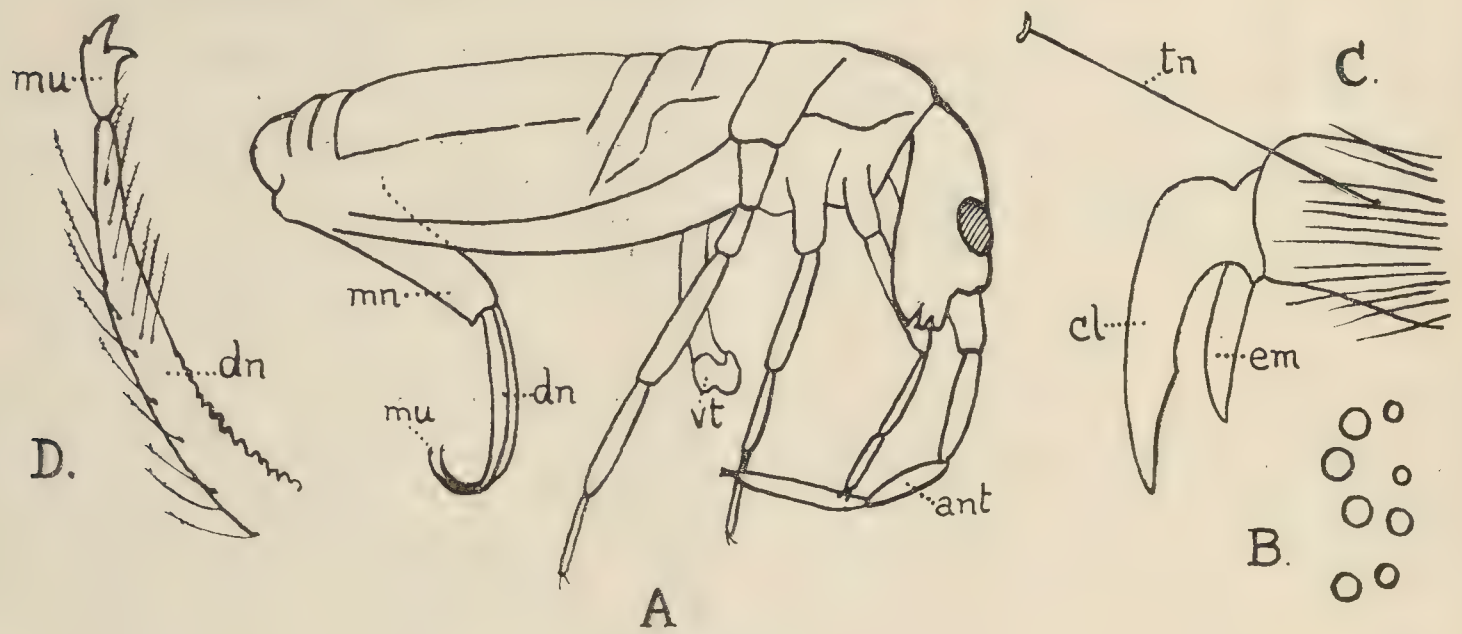

FIG. 13.—*Entomobrya mawsoni* Tillyard. Order Collembola, family Entomobryidae. Length, 2·5 mm. A, lateral view of whole insect; B, group of eye-elements, much enlarged; C, end of hind tarsus, much enlarged; D, end of dens and mucro of spring, much enlarged. *ant*, antenna; *cl*, claw; *dn*, dens of spring; *em*, empodium; *mn*, manubrium; *mu*, mucro; *tn*, tenent-hair; *vt*, ventral tube, or collophore.

New Zealand subregion—viz., *Entomobrya mawsoni* Tillyard (fig. 13)—for whose discovery we are indebted to Mr. Harold Hamilton, of the Dominion Museum. The somewhat elongate cylindrical form of the body is typical of this family.

A peculiar genus, *Axelsonia*, is known to exist in barnacles; species of this genus ought certainly to be found along the New Zealand coast if a careful search were to be made by marine collectors.

SUBORDER SYMPHYPLEONA.

This group is only represented in our region by the family Sminthuridae, or globular springtails, easily distinguished by the globular abdomen in which all traces of segmentation have been lost. A second very small family, the Neelidae, contains two rare genera in which the thorax is longer than the abdomen; it is confined to America.

Family 3. SMINTHURIDAE.

These tiny insects have great powers of leaping, and are not easy to capture. They are known to occur both in New Zealand and Australia, but so far not a single species has been described. *Arrhopalites davidi*

Tillyard is a minute, purplish-black species discovered by Mr. Harold Hamilton on Macquarie Island, in moss and crevices of rock; it has the last segment of the antenna long and annulated, and the spring ends in two long, slender, and similarly shaped mucrones.

Some species of this family are of economic importance, as they occasionally increase greatly and damage crops. Fortunately no such insects have yet been introduced into New Zealand; but the fact that Australia has suffered from occasional outbreaks shows that we need to be on the lookout for them.

THE ROCK-WREN *(XENICUS GILVIVENTRIS).*

By H. GUTHRIE-SMITH.

SOME twelve years ago, walking from Te Anau to the Sutherland Falls, I had noted on a certain flat-topped rock not far from the top of Mackinnon's Pass a brace of tiny brown birds—rock-wrens they were—curtseying, ducking, and telescoping, exploring the rocks, appearing and reappearing from crannies, fissures, ledges, and chinks. More rarely from time to time brief flights were taken, but always the little fellows returned to their boulder as to an established home.

I had been twice across the world since then; war had altered the boundaries of half the States of the Old World; in a dozen departments of human thought science had revolutionized the conceptions of men; yet in the immediate vicinity of that same rude platform the small rock-wren had managed to maintain his hold.

When in 1912 these wilds had been visited it had been autumn; now it was full spring on the mountain-sides. The gritty peat slopes were dotted with innumerable blossoms of the mountain-lily; as single plants or in great irregular clumps, their white flowers high above the deep-green shield-shaped leaves dotted and streaked the slopes. Among the stone and broken rock debris, often on the very edge of the track, grew silvery celmisias, some flat on the ground and woolly with soft tomentum, others low shrubs; there were stiff, straight-stemmed dracophyllums—plants no blast can bend or gale subdue; laden snowberries; prickly heaths; tiered ourisias, pubescent or smooth; whipcord veronicas; tough stringy brooms; scraps of the vegetable-sheep plant; geums with delicate cherry-like blossom; berried astelias; spear-grasses; violets; gentians; edelweiss; mosses, lichens; and mats of wiry high-country grass still flattened from the previous winter's snow. Above the forest-line the countryside was a huge rock-garden, with an outlook such as no artificial rock-garden, from the nature of things, can ever possess.

Looking downwards from the top of the pass, the bases of the mountains stood precipitous, sheer, unscalable; above the actual perpendicular cliffs there were grey naked steeps where no fragment of rock rested. Stripped by the elements even of grit, the broken ridges of the great range lay bleached and bare. Here and there whole mountain-sides had slipped in tumbled avalanches of broken rock, each of them for ever still after its one tremendous rush. The little river, no longer muffled beneath its blanket of snow or dumb in emerald ice, sang its gay summer song. So steep was

the descent it seemed as though a stone could have been dropped on to the tree-tops hundreds of feet beneath.

Birds move so little from localities once discovered to be suitable that I had determined in my mind that the breeding-quarters of one pair at least of rock-wren would be found near the spot where I had noted them in 1912. I had expected, furthermore, that the nest would be discovered, if discovered at all, built in some dry rock-cranny—in some such site, in fact, as is selected by the bush-wren (*Xenicus longipes*)—stone, of course, taking the place of timber. I had pictured an unsubstantial domed nest hidden away within shelter of dry rock.

We did discover our first pair of breeding-birds on the summit of the pass, on the very edge of the track, so near that our camera-legs straddled it; our photographic gear blocked the King's narrow highway. At first this was believed to have been a pleasant piece of good fortune; afterwards, when the nestlings were found to have been destroyed, we altered our opinion. We thought then that perhaps had we got a nest farther removed from the path an accident of this sort might have been less likely to happen.

On the top of the pass, first of all we noted a single bird; then that bird, or another, was detected with food in its bill; then the goings and comings of the pair were localized, yard after yard of untraversed ground being discarded from our field of vision. In this most fascinating of all games we grew "warmer" and "warmer," until in the end my daughter unravelled the mystery by detection of the faint, faint rasp of eager little feeders; searching still more closely, one of the parent birds flew almost into my face.

As there were half-grown chicks in this nest during the last week of November, and as I found another pair carrying food about the same date, eggs are probably laid in the beginning of the month.

The orifice of the nest pierced into a fibrous mass of overhanging roots. Partly within and partly beneath this densely matted live growth was built the nest. As we discovered afterwards when ransacking the deserted structure, its remarkable bulk was composed of skeleton leaves, finely shredded grasses, and feathers. On this comfortable cushion—the feathers were laid most thickly on the bottom of the nest—or, rather, within this overarching bower—reposed the chicks.

Of the 791 feathers counted, over seven hundred were those of *Ocydronus australis*, and perhaps those of *O. finschi* and *O. brachypterus*. There were feathers also in considerable numbers of the kakapo and kiwi, showing how high these species ascend in their alpine wanderings; there were also a few kea and a few pigeon feathers. When counted by us, in spite of desertion and the deluges of two preceding days, the interior of the nest and the feathers themselves were fresh and sweet; they betrayed no signs of mould or damp.

Unlike the bush-wren (*Xenicus longipes*), which is constantly taking dry feathers in and wet feathers out both during incubation of the eggs and rearing of the young, the rock-wren seemed to prefer to make a thorough job at the beginning. Warmth and dryness are attained once for all by bulk of material, the natural oil of the feathers massed together helping to exclude any dampness that might penetrate, firstly, through the live root-mass, and, secondly, through the exterior shield of shredded grass and skeleton leaves.

The powers of flight are greatly superior to those of the bush-wren, with which species I have fully dealt in a volume not yet out of the hands of

the printers. The rock-wren can fly comfortably 50 or 60 yards—downhill certainly, but with a sustained easy, unlaboured movement—no fern-bird's feeble flutter. The rock-wren, too, is much less of a ground-bird in its search for moths and other insect-life, often alighting upon and exploring the rounded tops of the shrubby hillside veronicas; the curtsey or bob, and then the tip-toe telescopic elongation of the little fellow is also more pronounced. However little differences museum specimens may show, there are well-marked dissimilarities in the live representatives of *X. flaviventris* and *X. longipes*.

Watching the birds at work, we noticed grasshoppers and big whitish spiders carried in for the hungry chicks; more rarely a worm was secured by scratching the drier surfaces of grit and peat. The nest was visited by one or other of the parents about every ten minutes. During the operation of feeding, or perhaps in eager anticipation of the event, the nestlings would emit an almost inaudible rasping cry like the faint winding of a lady's wrist-watch.

Of the several days devoted to observation of the home life of the rock-wren the first only gave us passable weather. The second was so bitterly bleak that our numb fingers refused their office, entire loss of feeling preventing pressure of the shutter-release. The third day, doubtful from dawn, developed into a terrific gale; torrents of icy rain fell, every precipice and bare slope was grey with innumerable waterfalls, white ragged clouds climbed the cliffs and tore over the tops—really an almost terrifying storm. In weather such as no man ever did birds-nest in before, or, I should imagine, ever will again, I persisted for a couple of hours; but though I came within a few yards of a second nest, cold and misery would not let me rest quiet, and the birds remained unsatisfied as to my presence and refused full confidence. I never found the tiny entrance of that second nest, but at any rate, disc vered that the little pair seemed in no wise perturbed by blasts that nearly whirled me from the mountain-side. No doubt during hundreds of centuries the species had become inured to the climatic conditions of Westland.

Xenicus gilviventris, I am glad to think, is one of the species likely to survive changes that from the forester's and field naturalist's point of view have desolated New Zealand. The ravages wrought elsewhere by deer, rabbits, opossums, birds, and other imported vermin are unlikely to affect the welfare of the rock-wren. Even weasels and rats—and I know they ascend to great heights—are hardly likely to draw sufficient recompense in prey from such unpeopled solitudes. Plant-life, furthermore, in these high altitudes and in this shower-bath climate is certain to remain undominated by an alien flora. The vegetable kingdom thus unaltered, native insect-life is consequently secure. With cover and food-supplies thus unmodified, the rock-wren may be considered relatively safe.

To this species, as to others threatened by the inroads of civilization, climate, climate, climate, when all else has failed, remains a tower of strength a city of refuge, the shadow of a great rock in a weary land. The assets of the Dominion are by no means limited to warmth of sunshine and refreshment of shower. In the wilds of New Zealand fierce gales, tempests prolonged, torrents of rain, perpetual wetness spell salvation to many an interesting breed. "O ye Frost and Cold, O ye Ice and Snow, O ye Mountains and Hills, bless ye the Lord, praise Him and magnify Him for ever!" must be the canticle of our little mountain-wren.

THE MECHANICS OF NATURAL FLIGHT.

By H. HARDCASTLE.

SOME of the principles involved in the flapping flight of birds were discussed in the May, 1924, issue of this *Journal* (pp. 44–49). The present paper deals with gliding flight, and to some extent with the amount of power required to maintain it. Gliding and soaring are closely related; in each case the bird performs no propulsive effort, and derives its motion from some force external to itself. Pure gliding is a passive surrender to the force of gravity; but it merges imperceptibly into flight methods in which the energy of moving masses of air is drawn upon to restore the height necessarily lost in a pure glide.

Flight with outstretched wings, moved only for purposes of steering and balancing, will be seen to differ from flapping flight in no particular except source of power; and the discussion of this power, so far as it affects sustentation, and as to its quantity, applies to both forms of flight.

Two questions arise for discussion—(1) What is the means of support? (already referred to as similarly involved in flapping flight, and deferred for consideration in this section); and (2) Whence comes the propulsive power? The first question is answered readily by the common theory of aerodynamics; it is precisely the same as arises in connection with artificial (aeroplane) flight. The second is much more elaborate, and only answerable in part.

Just as the horizontal propulsive force in flapping flight is provided by an oblique surface moving vertically, the vertical supporting force is provided by an oblique surface moving horizontally. The measure of the force depends upon the area of the wing; its vertical cross-section parallel to the line of flight; its "angle of incidence," or attitude relative to the plane of flight; and the velocity of motion through the air; and it is necessarily equal for normal horizontal flight to the actual weight of the bird. One of the most important factors in a wing calculation is what is known as the lift-drift or lift-resistance ratio—the ratio between the vertical force exerted by the air on the wing to the resistance offered to its passage through the air at flying velocity. This ratio is affected by the angle of incidence, which has an optimum value for a given velocity of the air-stream; and depends also in a most important way upon the cross-section of the wing.

A wing properly positioned for flight advances in an almost horizontal attitude: the plane in which its front and rear edges lies is inclined only a few degrees. At first glance the resulting lift seems to be due to the air trapped under the front edge being forced downward, so that the wing tends to move upward owing to the reluctance of the air below to be moved. This form of simple reaction undoubtedly plays a part in supporting the wing; but it is a minor part. Efficient wings, both natural and artificial, are "cambered," or convex, on the upper surface; and experiment shows that the curvature of the upper surface is all-important. The shape of the lower surface may be varied through a wide range without greatly affecting the performance of the wing. Actually if one unit of lift is contributed by the lower surface, approximately three units are

contributed by the upper surface. This is due to the fact that the curved surface imposes a continual downward acceleration upon the portions of the air that pass rearward over the wing, and is accordingly drawn upward with a force equal to that causing the acceleration of the air. The front edge of the upper surface actually dips downward so as to face forward; and this "dipping" front edge is the seat of the highest lifting-force.

This is not explainable simply by the theory of acceleration of air previously stationary. The upward acceleration that would be imparted would create an area of negative (*i.e.*, upward) pressure on the "dipping" front edge; but it cannot be shown that, in the presence of the air above, this will result in a net lift. What seems to be the correct explanation is ingeniously given by F. W. Lanchester (*Aerodynamics*, chapter iv). The flying bird is in reality a falling body, continually displacing air from below it to positions above it. All round a falling body there is a motion which is cyclic, and a little way from the body the air is moving upward. This is true even though the falling body is in rapid forward motion. There exists in front of the bird's wing, therefore, a narrow zone in which the air has an upward motion, and it is this air which the front edge of the wing attacks. The dipping front edge of the wing does not, in these conditions, present a negative angle of incidence, as it seems, at sight, to do.

This explanation is admirably illustrated by wing-sections appropriate to different flying-speeds. Slow-flying birds have deeply curved wings with steeply tilted front edges; fast travellers' wings are notably flat. In the one case the upward movement of air is well established in the portions met by the wings; in the other it is not. A similar differentiation of design is characteristic of artificial wing forms.

A further consequence of the dipping front edge is a profound effect upon the resistance to forward motion. The forces exerted by a fluid upon a solid surface are everywhere perpendicular to the surface. The total force on the dipping front edge is therefore inclined forward, and on resolution consists of a force which lifts the wing vertically, and a force which draws it forward . The latter force is therefore subtracted from the general resistance to flight, and produces the remarkable result that a cambered wing not only has a larger lifting-power, but, in spite of a greater apparent projected area, offers a lower resistance to forward motion. and thus increases the lift-drift ratio of the wing.

The actual lift of the wing is expressed by a coefficient, which is its proportion to the theoretical force that would be exerted by the stoppage of all the air impinging normally on a flat surface of equal area, perpendicular to the line of flow. Whereas the lift-drift ratio of a flat plate may be as high as 6·4 to 1, the lift coefficient is then only 0·21. Cambered wings may easily give lift-drift ratios more than twice as great for the same lift coefficient, and in some cases will give twice as big a ratio and twice as great a lift coefficient at the same time: that is to say, they will lift twice as much on the same wing area, with half the head resistance. This, however, is at the condition of maximum lift-drift ratio. By a change of angle both lift and drift are increased, though the ratio decreases. Some cambered wings give a lift pressure, at flight angles, considerably in excess of that impressed by air of similar velocity upon a flate plate perpendicular to the stream. (The pressure coefficient for such a plate is 0·62.)

The resistance to flight hitherto discussed does not include that due to "skin friction," the term commonly applied to the drag due to the viscosity of the air in the layers in the immediate neighbourhood of the wing surfaces. It is simply the net horizontal component of all the pressures perpendicular to all parts of the wing surfaces. "Skin friction," though neglected for the time being, and quite small, nevertheless cannot be omitted from an exact calculation. But it is not usually necessary to evaluate it in a practical problem. Its effect in flight is not distinguishable from that of the horizontal component of the pressure forces, and it is merged naturally in the latter, forming part of the "drift" in the practical lift-drift ratio. Considering the bird as a whole, of course, the resistance of the body has to be included also in the total resistance to be overcome. This is remarkably small, and is very carefully minimized in birds of high flight-velocities, in which such resistance becomes important owing to its variation as the square of the velocity. The air-resistance of a "fair-shaped" body may be as low as 2 or 3 per cent. of that which would be offered by the flat surface represented by its maximum cross-section.

An attempt may now be made to discuss the flight forces so as to show their proportions in the case of a hypothetical bird: Tables are easily available showing the pressures which are exerted upon plane surfaces exposed to air-streams of different velocities. If a plate is held so as to face a wind of 20 miles per hour, the pressure upon it will be roughly 1 lb. per square foot. The pressure varies as the square of the velocity. If a cambered wing is held in the same wind-stream at an angle of incidence of 10 degrees, the force at right angles to the flow—that is, the "lift"—will also be approximately 1 lb. per square foot. It may be even more. The "drag"—corresponding to the "head resistance" in a bird—will be roughly one-tenth—often less—of the "lift." This means, then, that a bird weighing 1 lb., and with wings measuring 1 square foot, will be sustained if it has a velocity relative to the air of 20 miles per hour; and it will have that velocity if it is able to exert or to obtain a propelling-force of $\frac{1}{10}$ lb., plus the very small force required to overcome the skin resistance of its body. The energy-expenditure required to maintain this velocity is the resistance multiplied by the distance traversed and is, in the case just outlined, approximately 180 foot-pounds per minute. This is equivalent to an expenditure of 1 horse-power by a 12-stone man. Such a rate of expenditure seems outrageous; but it is by no means impossible for a man in good condition to exert a full horse-power for a short period. He has only to run upstairs two steps at a time—a little more than three strides a second—to do it. That such an effort is extremely exhausting is due to the unaccustomed nature of the exercise, and, to the fact that man is not designed for any such rapidity of energy-production. The physiology of birds points to a high rate of energy-conversion. Their blood-temperatures are high; they are voracious feeders; and they are very large breathers. All these are indications of highly active metabolism.

The lift-drift ratio corresponds to what is, in aviation parlance, called the "gliding angle." In its practical application it simply expresses, in terms of the starting-height, the horizontal distance which a winged structure will fly under no other propulsion than the force of gravity. The lift-drift ratio of a flying-apparatus can therefore be measured by observation either of the vertical and horizontal forces, or of the angle of free

descent. Either method is easily adopted with an artificial flier. The first method it is perhaps possible, but certainly extremely difficult, to apply to a bird, because a live bird will not behave, and a dead one is not likely to be placed in the natural flight position. The observance of the gliding angle recommends itself; but that also is difficult and uncertain. One can watch birds by the hour and see plenty of them gliding; but one is never certain that they are unaffected by the wind, or that they are not maintaining their height at the expense of velocity, or of a number of other factors which deleteriously affect the observation. Dr. E. A. Hankin, a close student of Indian birds of prey, which are superb soarers, is of opinion that their gliding-angles are very poor; but he bases his conclusion upon the shape of the wing-section, which "appears" to him to be inefficient. The writer is convinced, from his observations of the gliding (not soaring) of gulls and albatrosses, that their gliding-angles are extraordinarily fine. An estimate of the angle is, however, beyond his ability. It may be remarked, however, that gulls may be seen to glide for long distances in calm air, on a course whose descent is imperceptible. This performance is evidently due to the conversion of momentum; the bird begins the glide at a high velocity and adjusts its angle of incidence to maintain a constant lift as its velocity decreases. But as the decline in velocity is at all events not readily observed, this also argues a small loss of velocity and therefore a low head-resistance and a high lift-drift ratio. Furthermore, the performance is readily repeated after a very few wing-flaps to recover the lost velocity.

An appreciation of the foregoing is important in connection with the obvious fact that flapping flight is not an exhausting exercise, or even one demanding a very large expenditure of energy. It has been shown that, on the basis of a 10-to-1 lift-drift ratio, a big bird has to work much harder than a man would care to do. Notwithstanding the birds' specialized muscular development and physiological processes, it is very much to be doubted whether, in most cases, they work nearly as hard as might appear necessary. Notice, for instance, the casual way in which a heavy bird will pass from flapping to gliding flight, and *vice versa*. Those birds which normally glide a great deal well repay a little study when the weather is not propitious. They sit down and wait for a change; but a degree of aerial motion which gives no indication of much power being available is sufficient to bring them all into the air, where they loaf their way through quite impressive feats of aviation.

The force required to raise and depress a wing in stationary air is greater than that needed to flap it in flight. In the first case all the air in its path is greatly moved; it all has to be moved to the opposite side of the wing, and much of the force is absorbed in the formation of a volume of turbulence. In the second case the motion of the wing is not really a beating at all. It amounts, in fact, to a periodic variation of the angle of incidence at which the wing moves forward. The common gulls, flying at about 18 miles per hour, make 140 wing-beats per minute, thus advancing 11 ft. or 12 ft. for each stroke. The trajectory of the wing-tip is therefore a wave-form curve much flatter than the unpractised eye will permit one to believe. It is obvious that the wing, in this motion so dissimilar from what it seems to be, is exerting the force requisite for propulsion; and an analysis of its real action seems likely to throw a good deal of light upon some of the still puzzling questions of non-flapping flight.

It is a singular and impressive fact that as one descends the scale of size the apparent expenditure of energy in flight becomes proportionately greater. The smallest known birds, the humming-birds, move their wings so fast that they are only seen as a haze; most insects' wings are invisible in flight. Small birds flap very rapidly, never soar, and glide very little. The bigger the bird the slower is the flap, and the more, generally speaking, flight tends to develop into gliding. Yet with this goes the fact that the wing-loading—the weight supported for a given area of wing—increases with the size of the bird, reaching a limit of less than 2 lb. per square foot. It is evident that the wing-loading must increase. If we keep all proportions constant in birds of varying size, we arrive at the following: One bird (purely imaginary) is 1 ft. long, has wings 1 square foot in area, and weighs 1 lb. Its wing-loading is 1 lb. per square foot. A bird 2 ft. long will have 4 square feet of wings, but will weigh 8 lb., and its loading will be 2 lb. per square foot. Similarly, a bird 4 ft. long will have a wing-loading of 4 lb. per square foot; the loading increases, in birds of a given design, directly as the linear measurement.

Quite early in the series we reach the limit which nature has set. The only escape is a change of design, such as that exemplified by the difference between a pigeon and an albatross. A pigeon weighing 16 lb. would be a sheer impossibility; its wing-loading would be somewhere about 5 lb. per square foot. The limitation of wing-loading appears to the writer to be the sufficient and sole reason for the deterioration of wings in such birds as the emu and the ostrich: they have simply passed through their evolution till they could no longer fly. The same reason may explain the existence of the wingless birds. The greater activity of small flying creatures, like that of small land-animals, depends upon the disparity of muscular power and weight when linear measures are altered. Whereas weights vary as the cube of the length, muscular pull varies with the cross-section of the muscle and thus decreases less, as size is reduced, than the weight does. The argument cannot be carried through with mathematical exactness, but it is very similar to that which explains why the flea is a better jumper for its size than the kangaroo, and why the elephant cannot jump at all.

It is perhaps worth while to mention at this point how wing-loading and speed are related. Aeroplanes have very high loading—as high, for certain types of machine, as 20 lb. per square foot. These loadings are found to be related to speed by a curve approximately parabolic. Twenty miles per hour, a very common bird-speed, corresponds to 1 lb. per square foot in aircraft practice. Half a pound is obtained at a speed of about 12 miles an hour; 3 lb. at 30 m.p.h.; 5 lb. at 40 m.p.h.; 10 lb. at 60 m.p.h.: and 20 lb. at 80 m.p.h. These are the lowest speeds at which such pressures can be obtained on the wings, and are not by any means the speeds most favourable to flight—*i.e.*, most economical of power.

The value of the lift attainable with a wing depends very largely upon its cross-section. Whereas 20 miles per hour has been mentioned as the flying-speed corresponding to a lift of 1 lb. per square inch, this proportion exists only for a specified form of wing-section. Suppose a flatter wing is concerned: the lift-drift ratio will decrease for that velocity, because to maintain the lift at its previous value the angle of incidence must be increased. The lift, with a flatter wing, can be regained with the full

lift-drift ratio by an appropriate modification of speed, at which the resistance is less than at the less speed with larger angle of incidence. Wing resistance behaves in an apparently anomalous manner; and Lanchester has stated that with wings designed for various speeds the resistances remain approximately constant for similar loading. This follows from the assumption that, at whatever gliding-speed is appropriate to the wing-shape, the lift-drift ratio may be made the same.

Thus, whatever the resistance may be, the maintenance of lift is solely a question of power; and the bigger the bird is the more efficient its wings must be — the higher the lift-drift ratio — for it to be able to fly. The bird's available power may be regarded roughly as proportional to its weight—that is, to l^3, where l is any one dimension of the bird. The resistance, being a proportion of the weight, also varies as l^3. The expenditure of power required for flight depends upon the velocity; it varies as l^3v. Increasing with both velocity and resistance it tends early to outstrip the possible values of l^3, and therefore to reach beyond the energy content of the bird's weight. This process may be slowed by keeping the velocity down; but v is an ungovernable quantity. The wing-loading is proportional (in similar designs) to l; and higher wing-loading demands higher velocity.

There is thus a limit to the size of the bird which can be carried by a given form of wing at any velocity which the power associated with it can impart. This limit can be extended in some degree by changing the shape of the wing to reduce its resistance coefficient, so that v may be increased for the same expenditure of power; and, conversely, by increasing the wing-area so that lower speeds are made possible by the reduced wing-loading. Both devices are adopted in nature up to the practical limit; and we find that—no doubt owing solely to the limitations of the structural materials and devices available—wing-loading reaches its limit at less than 1 lb. per square foot of actual wing-area. The extension of wings with reduced loading also has its limit, because expansive designs also produce intolerable strains on the structure.

Nevertheless, in special conditions birds impose on their wings very high loadings and travel at abnormal velocities. They do so by a partial furling (flexing) of the wings, which has the effect of reducing the head resistance. But they only do this when there is an abundance of energy available from the air. The furled-wing performance can best be seen at close quarters on board a steamer running into a strong head wind. Gulls, with their strong liking for the close companionship of stewards, and also, no doubt, for the benefit of the up-draughts created about the ship, often fly alongside in winds which blow at relative velocities approximating 50 miles an hour. At such times their wings are not more than half-opened; and an extension of the wing has a very sudden result: the bird is abruptly tossed into the air and falls rapidly behind the ship, simply because it has returned to its normal flying-trim.

SCALES OF FISHES AS AN INDEX TO THEIR LIFE-HISTORY.

By W. J. PHILLIPPS, F.L.S., F.R.G.S.

INTRODUCTION.

THAT we can find out many main events in the life-history of a fish by means of a study of its scales, and compute its age as accurately as a botanist can inform us of the age of a tree, is one of the triumphs of modern biological research. The purpose of this paper is to review briefly some of the work on scales to date, and to point out the great economic importance of this study as a means of determining in a most accurate manner the conditions of life in New Zealand waters. By a study of age in relation to fishes secured over a number of years the economic biologist will be able to accumulate data extremely valuable in regard to such questions as depletion and overfishing, and the formation of fishery regulations relative thereto. These problems have recently become important off the Californian coasts and in the North Sea. In no small measure like problems await solution in New Zealand, particularly in relation to introduced and indigenous fishes of this country.

HISTORICAL AND DESCRIPTIVE.

Hoffbauer, in the Berlin fishing journal *Allemeine Fischerei Zeitung*, 1898, was the first to demonstrate the possibility of a study of carp-scales as indicative of age. A number of English investigators took up the subject, and in the annual reports of the Fishery Board for Scotland, 1904, 1906, and 1907, Johnston first showed that the rings on the scales of salmon had a distinct relationship to the main periods of the life-history. In 1902 J. Stuart Thomson, of Plymouth, carried out an interesting research on the periodic growth of scales as an index of age in two families of marine fishes, the Gadidae and the Pleuronectidae. He showed by means of tabulated statistics that scale-growth is accelerated during the warmer season of the year and diminished during the colder season, in such a manner as to cause the formation of annual rings, much more closely set during winter than during summer. One paper on the subject, embodying several years' observation and study of trout-scales in Canterbury, has been published in New Zealand within recent years, by M. H. Godby, in *Trans. N.Z. Inst.*, 51, pp. 42–67, 1919. The conclusions drawn are of considerable value to the Canterbury Acclimatization Society, and general acclimatization in New Zealand; but conditions are rarely alike in many rivers widely separated, thus compelling us to the conclusion that a like work is necessary over many years in each of our many acclimatization districts.

A period in which adverse conditions were intensified to an extreme degree might cause a cessation of growth and render age-determination a rather difficult matter. For example, the quinnat salmon of Alaska, which seeks the river-mouth in May or June, when the surface temperature of the ocean approaches 40° F., passes through such hardship as to suspend growth for a small period (see fig. 1). Thus a salmon in its fifth year would

indicate in its scale structure the completion of four full years' growth, and the margin of the scale would be formed by the winter check of the fourth year.

Morphological.

In order to discuss the morphology of fish-scales, writers on the subject found it necessary to define the various areas of the scale in relation to each other and to the general symmetry. Writing of salmon-scales,

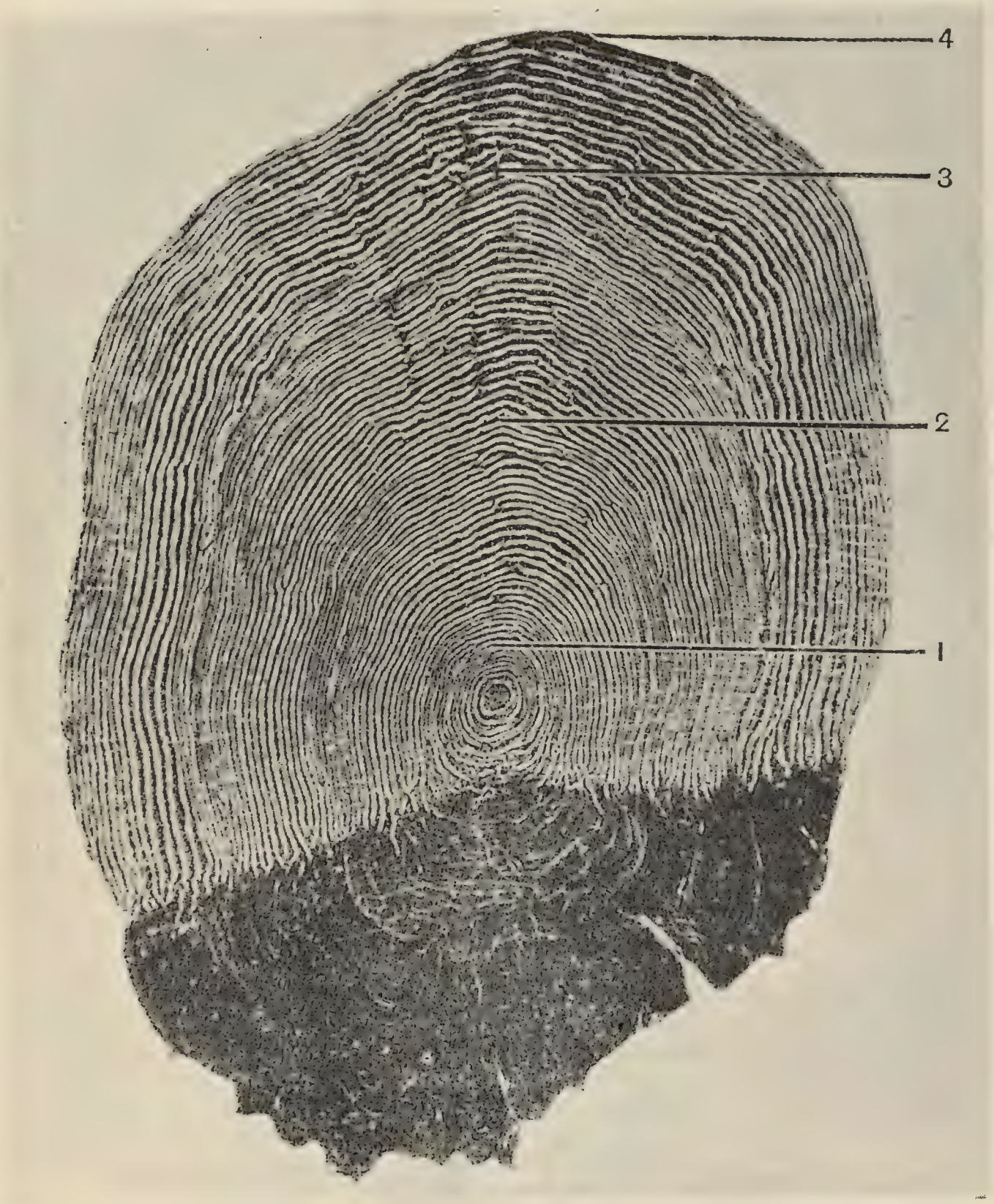

Fig. 1.—Scale of king or quinnat salmon taken from mouth of Yukon River, 18th June, 1920. (Male; 31½ in. long; weight, 14 lb.; in its fifth year.) After Gilbert.

Dr. Masterman, Superintending Inspector for Fishery Investigations to the Board of Agriculture and Fisheries, London, states as follows :—

"Radial axes may be selected leading from the centre to the periphery, which may be conveniently distinguished by reference to the symmetry of the fish." (See fig. 2.) "The most important and definite radii are the anterior and posterior, forming together the antero-posterior axis of the body. In the majority of scales this constitutes the long axis throughout

life, dividing the scale into dorsal and ventral halves. . . . At right angles the antero-posterior axis is the dorso-ventral axis, formed of dorsal and ventral radii. This axis divides the scale into anterior and posterior parts, which tend to differ markedly from each other both in structure and shape. The anterior part is deeply embedded in the dermal pocket, and is at the centre of active growth; the posterior part, especially in later life, tends to project from the general surface, covered by a fold of skin, and is the portion of least active growth and of greatest exposure."

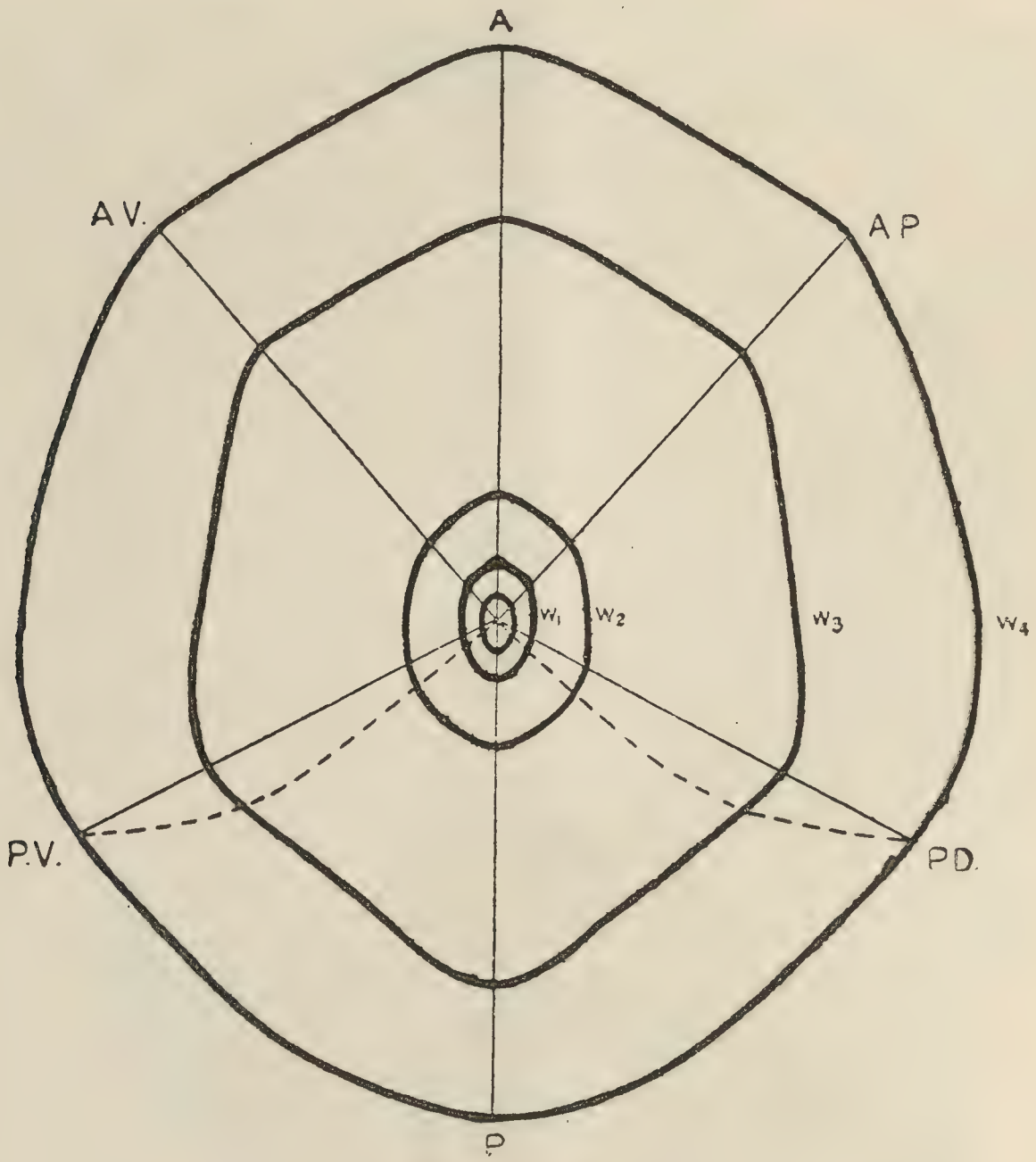

FIG. 2.—Diagram of the plan of symmetry in the scale of a salmon. A = anterior axis; P = posterior axis; A.V. and A.D. = antero-lateral axes; P.D. and P.V. = postero-lateral axes. W_1, W_2, W_3, W_4 = edge of scale at cessation of growth in winter of first and following years. Dotted line = line of termination of crescentic ridges. (After Masterman.)

THE SPAWNING-MARK.

On the scales of trout sometimes a spawning-mark is apparent, caused by the absorption of the rings in such a manner as to leave a blank circular space for the period in which spawning eventuated. This is exemplified in figs. 3 and 4.

Fig. 3 is from a male fish, 29 in. long, taken in the Tongariro–Taupo River on the 15th May, 1922. It had spawned in 1921, as evidenced by the ring of absorption, and had formed fifteen more rings up to date of capture.

Fig. 4 is from a female caught in Lake Taupo on the 2nd January, 1922. It was $25\frac{1}{2}$ in. long, and in its eighth year. Scales were submitted to the well-known expert and member of the Salmon and Trout Association of the United Kingdom, Mr. Hutton, who made the following diagnosis: Two

years in the river, one or probably two years in the lake; and then the fish spawned, and has spawned in each of the following three years: thus has spawned four times.

Fig. 5 is from a 12 lb. male fish taken in the Tongariro–Taupo River on the 16th May, 1922. It appears to be nine years old, and shows no spawning-mark.

Fig. 3. Fig. 4.

[*L. Jones, photo.*

Fig. 5.

Metabolism and Recent Investigation.

Many early workers were for some time sceptical of the results of scale-reading, as applied to all fishes, as being an actual record of past fact in the life-history. For example, Cummingham (*Ann. Rep. Fishery Board of Scotland*, 1905) considered that in the case of one family at least, the Pleuronectidae, or flat fishes, the scales were of little value for age-determination, for in most cases the zones were somewhat difficult to

distinguish and judgments must be confirmed and tested by examination of the otolith.

Much interesting investigation has been carried out since the above date; but it was not until 1918 that the scales of flat fish were comprehensively studied. In that year D. Ward Cutler (*Journ. Marine Biol. Stn., Plymouth*) published a preliminary account of the production of annual rings in the scales of plaice and flounders, and by means of a special method introduced by Winge, who examined the scales of cod in Germany in 1915, was successful in demonstrating that growth can be measured as accurately in the Pleuronectidae as in other fishes. Further, by means of keeping plaice and flounders under control and observation, he found that increased temperature was the main factor in the production of wide summer rings. Lower nutrition leading to poor condition resulted in the lessening of the number of sclerites produced, but did not affect the breadth. High food-consumption leads to a high sclerite formation. Thus the number of rings on a scale inform us of the general metabolism of the animal.

APPLICATION OF SCALE-READING AND CONCLUSIONS.

In the most exhaustive work on scales of fresh-water fishes yet published (Board of Agric. and Fisheries, *Fishery Investig.*, ser. 1, vol. 1, London), wherein the major work has been carried out by Dr. Masterman, considerable attention is given to all aspects of the problems of scale-reading. The number of years which the Atlantic salmon spends in the river, derived from a study of the centres of smolt-scales, is of considerable interest to New Zealand. In the River Wye Dr. Masterman found the following: One year, 0·2 per cent.; two years, 95·3 per cent.; three years, 4·5 per cent. Dr. Dahl, Director of Norwegian Fisheries, in his work on the age and growth of salmon and trout in Norway, 1917–19, finds as a result of investigation of 286 Norwegian parr and smolts caught in 1908 and 1909 that the ages at which these fish would have left the river were as follows: Two winters of river life, 31; three winters of river life, 116; four winters of river life, 23; five winters of river life, 63; six winters of river life, 1. As Dr. Masterman points out, the relative proportion of the different Norwegian groups means little, for they were rod-caught fish, and samples were obtained from four different districts.

Dr. Dahl has drawn attention to the fact that parr in the more northerly stations spend longer time in the river than those in the more southerly. Possibly temperature is the explanation. New Zealand climate varies considerably from north to south, and extends through more degrees of latitude than either Great Britain or Norway. By a study of river temperatures in different parts of New Zealand it may be possible in years that are ahead to carry out co-ordinated experiments on this and other problems.

Drs. Jordan, Gilbert, Evermann, and others have carried out very considerable researches on the salmon of California. On account of their great economic importance to the countries concerned, the life-histories of the various species of Pacific salmon found in the United States, Canada, and Alaska are better known than is the case with most river-fishes; but, recognizing that it was of almost equal importance to have a full knowledge of the environment in which eggs were laid and young hatched out, the United States Commission of Fish and Fisheries have latterly had investigators engaged in the elucidation of the life-histories of various other

small indigenous fishes. In New Zealand we have now established beyond a doubt both the quinnat and Atlantic salmon, and this brings the problem nearer home. What of our unique aquatic river fauna, in particular those indigenous fishes and insects which have without doubt decreased in numbers with the introduction of trout? What of the future of our whitebait industry, which could be made one of the country's important assets? Without thought of how little we actually know of our native fresh-water fishes, we have introduced rapacious strangers whose habits may differ considerably from the habits of their progenitors in the natural habitat. The quinnat does not appear to stay in the upper reaches of rivers more than one year, and possibly not as long as that. (I am investigating this point.) In New Zealand the Atlantic salmon, on the other hand, may not appear to sea until several years of age, though practical fishery inspectors have asserted that the young drift down the rivers tail first after hatching. As far as my researches show, many fish stay in the streams more than a year.

In a letter which I received from the Secretary of the Salmon and Trout Association of the United Kingdom I was informed that the experience of that association had been that trout will not thrive in rivers up which Atlantic salmon run. This statement is not without its significance for New Zealand. Blind acclimatization is the only term to describe the present rush to introduce fry of Atlantic salmon into every large river already stocked with trout. The balance of nature, the relation of plankton to animal life, must be maintained; irreparable harm can be the only outcome of neglect of the study of limnology in New Zealand.

MARINE BIOLOGICAL NOTES.

By MAXWELL W. YOUNG, F.C.S., Biologist, Marine Biological Station, Portobello, Dunedin.

REVERSED ACTION OF THE GILL-COVER IN TURBOT.

A REVERSAL of the usual action of the gill-cover of plaice kept in captivity has been recorded by Fulton.* The imported turbot (*Rhombus maximus*) at the Portobello Fish-hatchery have been frequently noted acting in a similar manner. In the normal process the fish take in the water through the mouth and pass it out through the gill-openings. At times, when swimming round their pond, being held almost vertical by its walls, practically the whole of the head projects above the surface of the water, and one can then notice small fountains of water being regularly expelled from the mouth, this proving that the water must have been taken in through the gill-openings and passed in a reverse manner through the mouth.

A trumpeter (*Latris lineata*) which has been in captivity for several years exhibits the same phenomena; but in his case the spouts are not nearly so pronounced, the turbot being able to send the water sufficiently high to splash any one leaning over the tank.

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* T. W. FULTON, Fish Bd. Scot., 1903, 22, 3, 287.

THE OCCURRENCE OF NOTOCLINUS FENESTRATUS (FORSTER) IN OTAGO HARBOUR.

This beautiful little fish is seldom captured in our waters, probably because it is rare, but possibly on account of its habitat. It lives amongst the weed, lying quietly along the fronds, which it closely resembles. As the places where weed is plentiful are shunned by the users of seine nets owing to the risk of dragging in a foul net and the subsequent damage to the gear, this may account for the paucity of specimens.

From a long series of observations on two specimens which we have held in captivity I do not think that it would be found in fast-running tidal currents, as it is a very weak swimmer. It is also unlikely that it would be captured by hook and line, as even with the example of good-feeding fishes in the same tank neither specimen showed any inclination to take the usual baits used for feed. We have so far captured only two specimens, and, as our records extend over a number of years, I think that this note is justified. Thomson* states that this fish is fairly common; but it may be like a lot of other fish which used to be common in the harbour but are now very rare. This is probably due to the excessive dredging and other harbour-works making the water sufficiently muddy to kill the small animals on which the fish feed.

The following is a record of the observations made on the specimens in captivity:—

(*a.*) Brilliantly coloured in red, gold, green, and black, with transparent tissue and spaces between the fin-rays. Date of capture, 11th August, 1922; died, 4th September, 1922; captive twenty-four days. Fed intermittently at first, then stopped.

(*b.*) More subdued colouring; uniform brownish-red when captured to a uniform bright green before death. Fins as in (*a*). Date of capture, 26th September, 1922; died, 6th May, 1923; captive seven months and ten days. This specimen would go for weeks at a time without touching food, and died in a terribly emaciated condition, being merely a skeleton covered with skin.

NOTE ON TUMOURS IN TURBOT.

Two of the turbot (*Rhombus maximus*) in captivity at the hatchery died under conditions necessitating a post-mortem examination. In both cases this revealed a large tumour on the under-side. These proved to be simple tumours of the striped muscles—"rhabdomyoma"—with degene a-tion and inflammatory changes. Their cause is unknown, but their growth was probably accelerated by the conditions under which the fish had been living for so many years, and their extreme age.

NOTES ON THE HABITS OF WHALEFEED (MUNIDA GREGARIA).

Munida gregaria in its swimming stage visits Otago Harbour in large numbers during the warmer months of the year. The shoals are so large that the water appears to be quite red with the thousands of individuals which are clustered together. The smaller shoals often take a circular shape like a swarm of bees, and the incessant motion of each individual tends to heighten this illusion. On attaining a certain size and during the

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* Hon. G. M. THOMSON, History of Portobello Hatchery, *Board of Science and Art Bull. No. 2*, p. 95.

winter months the crustacean goes to the bottom, and we have dredged specimens in up to 60 fathoms of water. When the shoals are on the surface the stomachs of most of the fish caught are found to be crammed with whalefeed. I placed several berried specimens dredged from 60 fathoms in an observation-jar, and they spawned on the 4th September, 1923. Mr. Anderton hatched out specimens (locality of capture unknown) on the 28th September, 1908, and 4th October, 1914, so it will be seen that the spawning-date is fairly constant. The appended table shows the occurrence of the swimming stage (previously known as *Grimothea gregaria*) inside the harbour limits. It will be seen that they are practically always present during December, January, and February, but the extent of the shoals varies considerably from year to year. They have been exceedingly plentiful during 1923 and 1924. When the spring shoals make their first appearance the individuals are nearly transparent, the eyes and a red spot on the carapace being the most prominent features; but they grow very rapidly, and the colouring becomes a more intense red as time goes on. By the beginning of December the whole of the body is a brilliant red, with a very much darker spot on the carapace.

Literature.—MSS. and journals at the hatchery; Hon. G. M. Thomson, *Board of Science and Art Bull. No. 2*, p. 104; C. Chilton, *Rec. Cant. Mus.*, vol. 1, No. 3, pp. 287, 301.

Table of Seasonal Occurrence of Whalefeed (Munida gregaria) *in Otago Harbour.*

Year.	Jan.	Feb.	Mar.	April	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.	Observer.
1898 ..	..	..	..	..	..	..	..	..	×	..	..	..	1	Thomson.
1904 ..	..	..	..	..	..	..	..	..	..	..	..	×	1	Anderton.
1905 ..	×	×	×	..	..	..	..	..	..	..	..	×	4	Anderton.
1906 ..	..	..	..	..	..	No	rec	ord.	..	..	..	..	0	Anderton.
1907 ..	..	..	..	..	..	No	rec	ord.	..	..	..	..	0	Anderton.
1908 ..	×	×	×	×	×	×	×	..	..	..	×	×	9	Anderton.
1909 ..	..	..	..	..	..	No	rec	ord.	..	..	..	..	0	Anderton.
1910 ..	×	×	×	×	×	×	×	×	..	×	..	×	10	Anderton.
1911 ..	×	×	..	..	..	..	..	..	..	..	..	..	2	Anderton.
1912 ..	×	×	..	..	..	..	..	..	..	..	..	..	2	Anderton.
1913 ..	×	×	..	..	..	..	..	..	..	..	..	..	2	Anderton.
1914 ..	..	..	..	..	..	..	..	..	×	..	×	×	3	Anderton.
1915 ..	×	×	×	×	..	..	..	..	..	..	..	×	5	Anderton.
1916 ..	×	..	..	..	..	..	..	..	..	..	..	×	2	Anderton.
1917 ..	..	..	..	..	..	No	rec	ord.	..	..	..	..	0	Adams.
1918 ..	×	×	..	..	..	..	..	..	..	..	..	..	2	Adams.
1919 ..	×	×	×	×	..	..	..	..	..	..	×	×	6	Adams.
1920 ..	×	..	..	..	..	..	..	..	..	..	..	×	2	Adams.
1921 ..	×	..	..	..	..	..	..	..	..	..	×	×	3	Young.
1922 ..	×	×	..	..	..	..	..	..	..	..	×	×	4	Young.
1923 ..	×	×	×	×	×	×	..	×	..	..	×	×	9	Young.
1924 ..	×	×	×	×	..	..	..	..	..	×	×	×	7	Young.
Total	15	12	7	6	3	3	2	2	2	2	7	13	..	

THE HEART-BEAT IN DEAD DOGFISH.

A small dogfish captured in the seine net was placed in a pond at the hatchery, but was apparently too far gone to revive. After it had turned over on its back and all movements of the gills had ceased it was taken from the water and left lying on the floor for two hours. I then opened the whole of the abdomen, wishing to inject the brain through the aorta, and was surprised to notice that the heart was still beating rhythmically. The beat was quite regular for some eight minutes, then started to labour and slow down, finally ceasing twelve minutes after the abdomen was opened. It responded to such stimulus as pressure with the point of a scalpel for a further half-dozen beats, after which no ordinary stimulation could excite the slightest movement. The total time from apparent death to cessation of the heart-beat was two hours and a quarter.

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THE following notice relative to the competition for the Donovan Astronomical Essay Prize is forwarded by the secretary of the British Astronomical Association, New South Wales Branch :—

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In terms of the gift of Thomas J. Donovan, Esq., the Trustees appointed to administer the gift—viz., the Chief Justice of the Supreme Court of New South Wales, the President of the Royal Society of New South Wales, and the President of the New South Wales Branch of the British Astronomical Association—invite from scientists and students resident in Australasia, subject to the conditions hereunder mentioned, essays, in competition for the first "Donovan Prize," on the following subject: Photo-electric Theory and Technique, and its Application to Astronomical Research.

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2. The essay is to be submitted in triplicate.

3. All essays are to be received on or before the 7th May, 1925. They are to be addressed "The Director, Riverview College Observatory, Riverview, Sydney," and endorsed "Donovan Prize Essay." After the award is made, unsuccessful competitors may have their essays returned.

4. Each essay must be accompanied by a statutory declaration by the competitor setting out facts showing that such competitor is a *bona fide* resident in Australasia.

5. The first "Donovan Prize" will be twenty guineas.

6. If in the opinion of the trustees no essay is worthy of being awarded the prize, then the prize shall not be awarded.

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COLLISIONS BETWEEN THE PLANETS OF PASSING STARS.

A Special Type of Celestial Encounter.

By A. C. GIFFORD.

THE universe appears to be composed of an innumerable host of bodies and systems of many different kinds, all endowed with terrific activity. The scale, however, is so great that, with the exception of our immediate surroundings, the whole gives the impression of stability and repose. Whatever the stress and turmoil which surround us on Earth, we feel that "Stars silent rest o'er us." It is sometimes thought that a knowledge of the grandeur of the heavens and the insignificance of our Earth amongst celestial bodies must tend to discourage or overwhelm us by suggesting the slight importance of terrestrial things. It is quite otherwise. The infinitesimal has been proved to be as marvellous as the immense. The universe is one, and it is a universe in which it is a privilege to play even the humblest part.

We cannot hope to study the evolution of cosmic systems by witnessing their development. Civilizations rise and fall, whilst the Milky Way remains immutable. We may, however, gain some valuable cosmological hints from this very fact of the apparently changeless aspect of a universe in which we know that every atom, body, and system is for ever manifesting intense energy, and moving, for the most part invisibly, with incessant and inconceivable rapidity. Stars and systems, moreover, are found to be, at the present moment, in all stages of their respective life-histories. Some are apparently young and immature, others are old and decadent. It is clear that they must have started their life-cycles, or have been revivified, at widely different epochs. Bodies and systems must rise from obscurity to take the places of those which sink into darkness after manifesting a prodigal outpouring of energy during their luminous life. But, whilst every

star, and even every cosmic system, is sure to fade, we have not the slightest hint that the universe itself is growing old. It seems presumptuous for man even to frame a theory of cosmogony. However far we look back into the past, there is no indication whatever of a beginning. The universe appears to enjoy perpetual youth. The problem we should seek to solve is not its origin, but the nature of the elixir which prolongs its life for ever. One possible key to the enigma suggests itself instantly to any one who considers the question—but most astronomers think the explanation too simple and obvious to be true : it is that celestial encounter is the life principle of the universe. If stars and systems in their never-ending journeys through the vastness of space do ever meet other stars or systems, the phenomena which must result appear to supply exactly the stimulus required for revivification.

But do such meetings ever take place ? Astronomers, impressed with the vast distances which separate the stars, assert that collisions do not occur, and that even moderately close approaches amongst the heavenly bodies are far too rare to merit any serious study. But this denial is founded on several assumptions which are hard to justify. These are that the distances of the Sun from its luminous neighbours are typical of all stellar distances ; that non-luminous matter does not greatly alter the problem ; and that the time available for cosmical evolution is limited. If, however, we believe that many parts of the galaxy are far more crowded than the neighbourhood of the Sun, that the stars we see form only a small fraction of those which exist, and that the universe as a whole will be as perfect and as young a billion or a trillion years hence as it is to-day, then surely we must believe that dark stars and invisible systems can be, and indeed are, revivified to run their course again. If the number of stars was strictly limited, if none existed which we do not see, if time were short and the universe shorn of its immortality, then we might expect encounters to be rare and collisions improbable. But now that the existence of dark stars and non-luminous nebulae has been proved, and now that we can set no bounds to the duration of the past or of the future, celestial encounters appear not only probable but inevitable, and their fuller recognition will be found to provide a key to many a mystery.

Encounters may take place between bodies or systems of any or every kind, so their variety is infinite. Infinite also are the possibilities of cosmic construction which they suggest.

If celestial encounters are to be studied systematically, some system of classification will be indispensable. For the present we divide such encounters roughly and provisionally into classes as follows :—

Types of Celestial Encounters :—

I. Encounters within a single stellar system, such as those of comets or meteoric swarms with the Sun, or with planets or their satellites, or with one another.

II. Encounters in which stars or their planets are involved.

III. Encounters of stars with gaseous nebulae.

IV. Encounters in which clusters, nebulae, or other cosmic systems are involved.

In this paper we shall consider one particular type of encounter contained in the second group, so it is necessary to specify the place it occupies in the general scheme.

We divide the second group as follows :—

Stellar Encounters :—

A. Meetings between two single stars without any planetary systems.

B. Meetings between two single stars of which one is solitary and the other has a family of planets.

C. Meetings between two single stars each with a family of planets.

D. Meetings between a single star and a binary system, with or without planets.

E. Meetings between binary systems.

F. Meetings between two systems, one of which is, or both of which are, multiple.

Each of these types of encounter may then be further divided. Within type A there are the following varieties :—

(1.) A passing so distant that its effects are barely perceptible from stellar distances.

(2.) An approach so close as to raise considerable though transitory tides.

(3.) An approach which causes tidal disruption in one or in both of the bodies.

(4.) A grazing collision.

(5.) A collision which weds the two stars into a single system.

(6.) An encounter so complete that whirling coalescence ensues.

(7.) A collision so nearly direct that the ensuing pulsation becomes more important than the rotation.

The problem in every case is made much more complex by the fact that the phenomena accompanying the encounter depend largely on the particular stage which each unit has reached in its life-history : whether, for instance, the star is a giant, a dwarf, or a dark, dead sun.

The other types may be divided in a similar way, but the complexities increase when we pass from stars to systems. In B, for instance, complications are introduced by the perturbations of the planetary orbits and the possibility of a collision between the solitary star and a planet of the other one. In C, in addition to the cases already mentioned, there is that which is the subject of this paper. If the stars themselves clash, the two families of planets may be whirled into a single system, some may become involved in the central conflagration, and possibly some may escape from the system. In D, E, and F the complications become innumerable.

Very few of the special cases of encounter have been studied in detail. In group A the first two varieties are less interesting than the others. A (3) has been studied by Chamberlain and Moulton, Jeans, and others. A (4) was shown by Bickerton in 1878 to correspond to the birth of a typical nova. A (6) is the type of encounter which appears likely to lead to the formation of a solar system.* A (5) appears to lead to double stars or spectroscopic binary systems. A (7) suggests the origin of Cepheid variables.

A collision in which any considerable portions of the two stars are involved appears almost certain to result in the formation of planetary systems. It seems probable, therefore, that solitary suns are exceptional. Now, if most stars are accompanied each by its own family of planets, an

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* *N.Z. Jour. Sci. & Tech.*, vol. 7, No. 1, p. 7.

encounter in which a planet of one star meets a planet of another may be more common than one in which the stars themselves meet, just as the expulsion of an electron is more easily effected than the disruption of the nucleus of an atom. What phenomena should be expected when planets clash in this way is therefore worth careful consideration.

As an introduction to this subject let us consider the statement of Flammarion* that if two planets were to meet in their course they would be raised to such a high temperature that they would disappear in vapour and would form an immense nebula.

A collision such as that referred to by Flammarion is, of course, purely hypothetical. There is no likelihood of such an encounter ever occurring; but before passing on to a discussion of the important type which is the subject of this paper it may be of interest to discuss Flammarion's statement in detail. It will be seen at once that the effect of such a clash must depend very largely on which particular pair of planets is involved. If we take two of the smaller planets which are comparatively near the Sun, and which therefore move rapidly in their orbits, we shall find Flammarion's statement accurate; but if we take two of the massive planets, which, owing to their greater distance from the Sun, are moving more slowly, we shall find that the statement fails to represent the facts.

We take Flammarion's statement to imply that the planets are to meet with the actual orbital velocities which they possess: that is, we are not to take any account of their gravitational attraction. We shall suppose that the two bodies collide directly, their velocities being oppositely directed in the same straight line. The total momentum of the system remains unchanged, and this fact gives us the velocity of translation of the combined mass after impact. It is then easy to calculate the kinetic energy which is transformed into heat.

If m_1, m_2 be the masses of the two planets, and v_1, v_2 their velocities, and v the velocity of the combined mass after impact, $m_1v_1 - m_2v_2 = (m_1 + m_2)v$. The kinetic energy before impact is $\frac{1}{2}m_1{v_1}^2 + \frac{1}{2}m_2{v_2}^2$; that after impact is $\frac{1}{2}(m_1 + m_2)v^2$. The loss of kinetic energy during impact is then

$$\frac{1}{2}\frac{m_1m_2}{m_1 + m_2}(v_1 + v_2)^2$$

an expression which can, of course, be obtained from the ordinary formula by equating the coefficient of elasticity to zero.

Dividing the above expression by $m_1 + m_2$ we get the average molecular kinetic energy per unit mass, a quantity which we require to use constantly in all these problems. In referring to this quantity we shall use the term "kinetol," suggested by Professor Bickerton. Dividing the kinetol (expressed in ergs per gramme) by the constant representing the mechanical equivalent of heat, we express the energy in terms of the number of calories per gramme. For the energy per unit mass when so expressed we shall use Bickerton's term "thermatol."

In considering the effects of a collision there are two other quantities, besides the kinetol or thermatol, of which we require to know the numerical values. These are (i) the critical velocity of escape from the surface of the body, (ii) the energy which would be required for the complete dissipation of the body considered as a homogeneous sphere composed of a single element.

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* FLAMMARION and GORE, *Popular Astronomy*, 1907, p. 216.

The critical velocity of escape from the surface of a homogeneous spherical body of mass M and radius R $= \sqrt{\frac{2GM}{R}}$. The critical kinetol $= \frac{GM}{R}$. That is, the critical kinetol varies directly as $\frac{M}{R}$, whilst the critical velocity varies as the square root of this quantity.

Thus if two equal spherical bodies form a single sphere of double the radius of one of them, the critical velocity of escape and the critical kinetol are each unchanged; but if the two form a sphere of the same radius as one of the original bodies the critical kinetol is doubled, and the critical velocity of escape increased to 1·4142 times its original value. If the two were to form a single sphere of the same density as the original bodies, the volume being twice that of one of them, the radius would be $\sqrt[3]{2}$ times that of one. The critical kinetol would then be $2/\sqrt[3]{2}$ (that is, 1·5874) times that of one, and the critical velocity $\sqrt{1{\cdot}5874}$ (that is, 1·2599) times the critical velocity of one.

If the two bodies differ in mass but have the same critical velocity of escape, then

$$\frac{M_1}{R_1} = \frac{M_2}{R_2} = \frac{M_1 + M_2}{R_1 + R_2}$$

where M_1, M_2, R_1, R_2 are the masses and radii respectively. If two bodies, related in this way, form a new sphere with a radius equal to the sum of their radii, neither the critical kinetol nor the critical velocity of escape will be altered. In other words, the energy liberated by the collision of two such spheres, if entirely gaseous, when drawn together from infinity by gravitation, is completely used up in the expansion of the resultant body to a radius equal to the sum of the two radii.

Now, the energy required for the complete dissipation of a homogeneous gaseous sphere composed of a single element is equal to the work done in forming the sphere by attraction from the state of an infinitely diffused nebula. Expressed as kinetol—that is, energy per unit mass—this work is $\frac{3}{5}$ of the parabolic or critical kinetol at its surface. This is proved as follows:—

To find the work done in the condensation of a homogeneous star from an infinitely diffused nebula: The work done in attracting to the surface of a homogeneous sphere of radius r and density ρ a shell of thickness dr and the same density is

$$\frac{G \cdot \frac{4}{3}\pi r^3 \rho \cdot 4\pi r^2 \cdot dr \cdot \rho}{r} = \tfrac{16}{3}\pi^2 \rho^2 G \cdot r^4 dr$$

where G is the constant of gravitation. The total work in forming a star of radius R is then

$$\tfrac{16}{3}\pi^2 \cdot \rho^2 \cdot G \int_0^R r^4 dr = \tfrac{16}{15}\pi^2 \rho^2 GR^5 = (\tfrac{4}{3}\pi R^3 \cdot \rho)^2 \cdot G \cdot \frac{3}{5R} = \tfrac{3}{5}\frac{M^2 G}{R}$$

The energy per unit mass is

$$\tfrac{3}{5}\frac{GM}{R}$$

That is, the kinetol produced $= \frac{3}{5}$ of that of a mass falling from an infinite distance on to the surface of the sphere. The kinetol necessary, therefore, for the complete dissipation of a homogeneous sphere is $\frac{3}{5}$ of the critical kinetol at its surface.

This gives an easy method of predicting the result of a collision between stellar bodies. We have only to compare the actual kinetol at any stage with that required for complete dissipation. It is necessary to make some assumption as to the radius of the resulting body at the moment the comparison is made. It will generally be convenient to choose the time when the radius of the body formed by the collision is either (i) equal to that of one of the bodies, (ii) equal to the sum of the original radii, or (iii) such as to make the density the same as before.

If the bodies which collide are equal uniform gaseous spheres the energy requisite for complete dissipation, being $\frac{3}{5}$ of the original critical kinetol, will in the three cases be (i) $\frac{6}{5}$; (ii) $\frac{3}{5}$; or (iii) 0·9524 times the critical kinetol of one of the original bodies.

As planets differ in density as well as in size and mass, it will be simplest, in considering the special type of collision suggested by Flammarion, to estimate the energy available for further expansion when the two form a sphere of the original size of the larger. The mass being the sum of the original masses, the critical kinetol will be $1 + \frac{M_1}{M_2}$ times that of the larger before collision, and the average kinetol necessary for complete dissipation will be $\frac{3}{5}$ of this.

It will be sufficient to glance at a few special cases. We shall choose—(1) A collision between Mercury and Venus; (2) one between the Earth and Mars; (3) one between Jupiter and Saturn; (4) one between Uranus and Neptune; and then, as a case in which one is very small and the other very large, (5) one between Mars and Jupiter.

Mercury and Venus.—Consider Mercury and Venus to come into direct collision with their present orbital velocities of 29 and 21·7 miles per second respectively. The mass of Venus is approximately fourteen times that of Mercury. Taking the mass of Mercury as unit mass, and using the symbols as before, $(m_1 + m_2)v = m_1v_1 - m_2v_2$,

$$v = \frac{274{\cdot}8}{15{\cdot}} = 18{\cdot}32.$$

The velocity after impact = 18·32 miles per second. The kinetic energy before impact = 3,716 units; after impact = 2,517 units. The loss of kinetic energy is approximately 1,200 units; therefore the loss of kinetic energy per unit mass is 80, and the average molecular velocity produced by the collision = 12·65 miles per second. The critical velocity at the surface of Venus is 6·37 miles per second; that at the surface of a body of the same size but with $\frac{15}{14}$ of the mass is 6·6 miles per second. The kinetol corresponding to a velocity of 6·6 miles per second = 21·8 units; that required for dissipation = $\frac{3}{5}$ of this value = 13·1 units. The available energy per unit mass is thus over six times that which would be required for complete dissipation if the planets were composed of a single element. With the varied chemical composition these planets have, the lighter elements will carry away a great deal of the surplus energy, but, even

allowing for selective molecular escape, the heavy elements will probably retain sufficient energy to scatter widely. The lighter elements will be dissipated with high residual velocities through space. Flammarion's statement is thus accurate in the case of Mercury and Venus.

The Earth and Mars.—Taking the mass of the Earth as unity and that of Mars as 0·106, and the velocities as 18 and 14·9 miles per second respectively, we find that the loss of kinetic energy per unit mass which results from a direct collision = 46·9 units. This implies a molecular velocity of mean square of about 9·68 miles per second. Supposing the two bodies to form momentarily a sphere the size of the Earth with a mass 1·106 times as great, the critical velocity of escape from its surface will be 7·3 miles per second. The actual molecular velocity of mean square is about $\frac{1}{3}$ greater than the parabolic velocity of escape from the surface. The kinetol required for complete dissipation is approximately 16, which is very little more than $\frac{1}{3}$ of the actual. The light elements will carry away most of the excess energy, and probably a small nucleus of heavy elements will be left behind.

Jupiter and Saturn.—The masses of these planets are respectively 314 and 94 that of the Earth, whilst their orbital velocities are 8 and 6·2 miles per second. On collision the loss of kinetic energy per unit mass = 17·8 units, which corresponds to an average molecular velocity of mean square of under 6 miles per second. Now, the critical velocity of escape from the surface of the combined mass when it is of the volume of Jupiter is 42 miles per second. The available energy per unit mass is thus only $\frac{1}{50}$ part of the parabolic kinetol—that is, $\frac{1}{360}$ part of the energy required for complete dissipation if of uniform composition. The energy transformed into heat by the collision is only sufficient to produce a slight enlargement of the diameter of the resulting body, and none but the lightest elements have any chance of escape. Flammarion's statement does not hold good in the case of Jupiter and Saturn.

Uranus and Neptune.—The masses are 14·4 and 16·7 times that of the Earth, and the velocities 4·3 and 3·1 miles per second respectively. The loss of kinetic energy on collision is equivalent to an average molecular velocity of about 3·87 miles per second. The critical velocity of escape from the combined body when of the size of Neptune is about 18 miles per second. The available energy per unit mass is a little less than $\frac{1}{20}$ of the parabolic kinetol, or about $\frac{1}{12}$ of that required for complete dissipation if homogeneous. In this case also Flammarion's statement fails to represent the facts.

Mars and Jupiter.—We choose this pair on account of the great inequality of mass. Jupiter and Mercury would be even better as an illustration, except for the uncertainty as to the mass of Mercury. The masses of Mars and Jupiter are respectively 0·106 and 314 times that of the Earth. Their orbital velocities are 14·9 and 8 miles per second respectively. The loss of kinetic energy per unit mass is 0·088 unit, corresponding to a molecular velocity of 0·42 mile per second, which is less than $\frac{1}{88}$ part of the parabolic velocity at the surface of the combined mass. The kinetol required for dissipation is thus over 4,600 times greater than that which is available, and hardly any material escapes. The enlargement of the diameter is extremely slight, and Flammarion's statement fails.

We see, then, that it is only accurate in the case of inner planets, which have high orbital velocities and comparatively small masses.

COLLISIONS BETWEEN PLANETS OF PASSING STARS.

There is no likelihood of the occurrence of any collision of the type so far as considered, and a discussion of the effects of such impacts possesses merely theoretical interest. We pass now to encounters of considerable cosmic importance.

It must sometimes happen, as stellar systems fly past one another, that planets of these systems meet. There is room for infinite variety in the resulting phenomena. The encounter may be of any kind, from the merest graze to direct impact. The planets may be small or large, dense or diffused; they may be circling with high velocity close to their parent suns, or slowly traversing orbits of immense diameter. The systems may have had high initial relative velocities, or none; the planes of revolution of the planets may make any angle with the lines of motion of the stars, and the orbital velocities may either increase or diminish the severity of the impact. But varied as these encounters are, they agree in giving rise to bodies more or less thermodynamically unstable. They all afford excellent examples of what Bickerton calls "augmented energy." Many of them result in a succession of phenomena similar to those of a typical nova, and differing only in intensity from those following the grazing impact of two stars.

The history of a body resulting from a celestial collision is determined chiefly by the kinetic energy of its molecules. We must endeavour, therefore, to get an approximate estimate of this quantity in some of the simplest typical cases.

When the stars themselves collide it makes all the difference whether the collision is partial or complete. It is the grazing collisions only which lead to thermodynamically unstable bodies. But in considering the planets of passing stars it will be sufficient to consider the effects of direct impacts.

The third bodies produced by grazes are necessarily more unstable than those formed by collisions which result in complete coalescence. If, therefore, we find in any particular case that a direct collision results in the entire dissipation of the mass, we may be certain that the third body produced by a grazing impact of the same two bodies, under similar conditions, would be even more evanescent. In considering special cases we shall find it convenient to deal with several sources of energy, in the following order :—

(1.) The kinetol due to the gravitational attraction of the two stars during their approach.

(2.) The kinetol due to the approach of the planet to a position at a smaller distance from the other star than that of the stars from one another—that is, from a position of lower to one of higher potential.

(3.) The kinetol due to the attraction of the planets for one another.

(4.) The kinetol due to original proper motion.

(5.) The kinetol due to the orbital motion of the planets.

The first three of these sources of energy are easily dealt with, as their effects are always additive. The fourth will also generally increase the intensity of the collision. The fifth source of energy is much the most difficult to deal with. No great accuracy is necessary. All that we need is to determine the order of magnitude of the quantities involved. They

vary between wide limits, and we shall try to fix approximate maximum and minimum values.

We shall consider two cases: (i) That in which the relative proper motion is sufficiently small to be neglected; (ii) that in which it is considerable—say, 20 miles per second. To get an approximate estimate sufficient for our purpose we may find the velocity due to the first four sources of energy, and then, by the parallelogramic law, compound with it the orbital velocity.

The original planes of orbital motion of the planets may be in any position with regard to the line of approach of the two stars. The planetary orbits will undergo great perturbations before the actual collision, which may take place in any part of the orbit. The motion of revolution round the parent star may either increase or diminish the violence of the impact. The planets will undergo violent tidal deformation.

To make the calculations as simple as possible we shall consider each star to be equal to our Sun, each colliding planet to be equal to one of the planets of the solar system, and the orbital planes either to coincide with the plane of motion of the two stars or to be at right angles to it. Disregarding perturbation, we can find extreme values for the energy in each case. The effects under other circumstances will be intermediate between those corresponding to these extremes. To facilitate the calculations we can make use of the tables on page 39 of the *New Zealand Journal of Science and Technology*, vol. 3, No. 1. To find the numbers corresponding to sources 3 and 4 we may use the accompanying diagram (fig. 1).

The kinetic energy due to the motions of translation is converted by the encounter into thermal energy: it will therefore be more convenient to measure it as thermatol—that is, energy per unit mass expressed in calories per gramme. To get the numerical value we have to divide the measure of the kinetol in ergs per gramme by Joule's equivalent—viz., $4{\cdot}18 \times 10^7$.

The third source of energy may be very simply disposed of, since we are considering the colliding planets to be alike. We have seen that the work of forming a homogeneous gaseous sphere of mass M and radius R is

$$\tfrac{3}{5}\,\frac{GM^2}{R}$$

Therefore the work of forming two such isolated spheres is

$$\tfrac{6}{5}\,\frac{GM^2}{R}$$

But the work of forming one sphere of mass 2M and radius 2R is

$$\tfrac{3}{5}\,G \times \frac{4M^2}{2R} = \tfrac{6}{5}\,\frac{GM^2}{R}.$$

This shows that the work of forming two isolated spheres each of radius R and mass M is the same as that of forming a single sphere of mass 2M and radius 2R from a state of infinite diffusion. So if two like gaseous spheres are drawn together from an infinite distance and collide, the energy liberated by the collision is just sufficient to cause the expansion of the combined mass till its radius is double that of one. The critical kinetol of escape is the same for this sphere as for one of the original spheres. We

can therefore consider that the energy due to the third source—viz., the gravitational attraction of the two planets for one another—is used entirely in making a body of twice the radius, which would have the same critical velocity of escape, and which, if there had been no other sources of energy, would be at the same temperature as the original planets.*

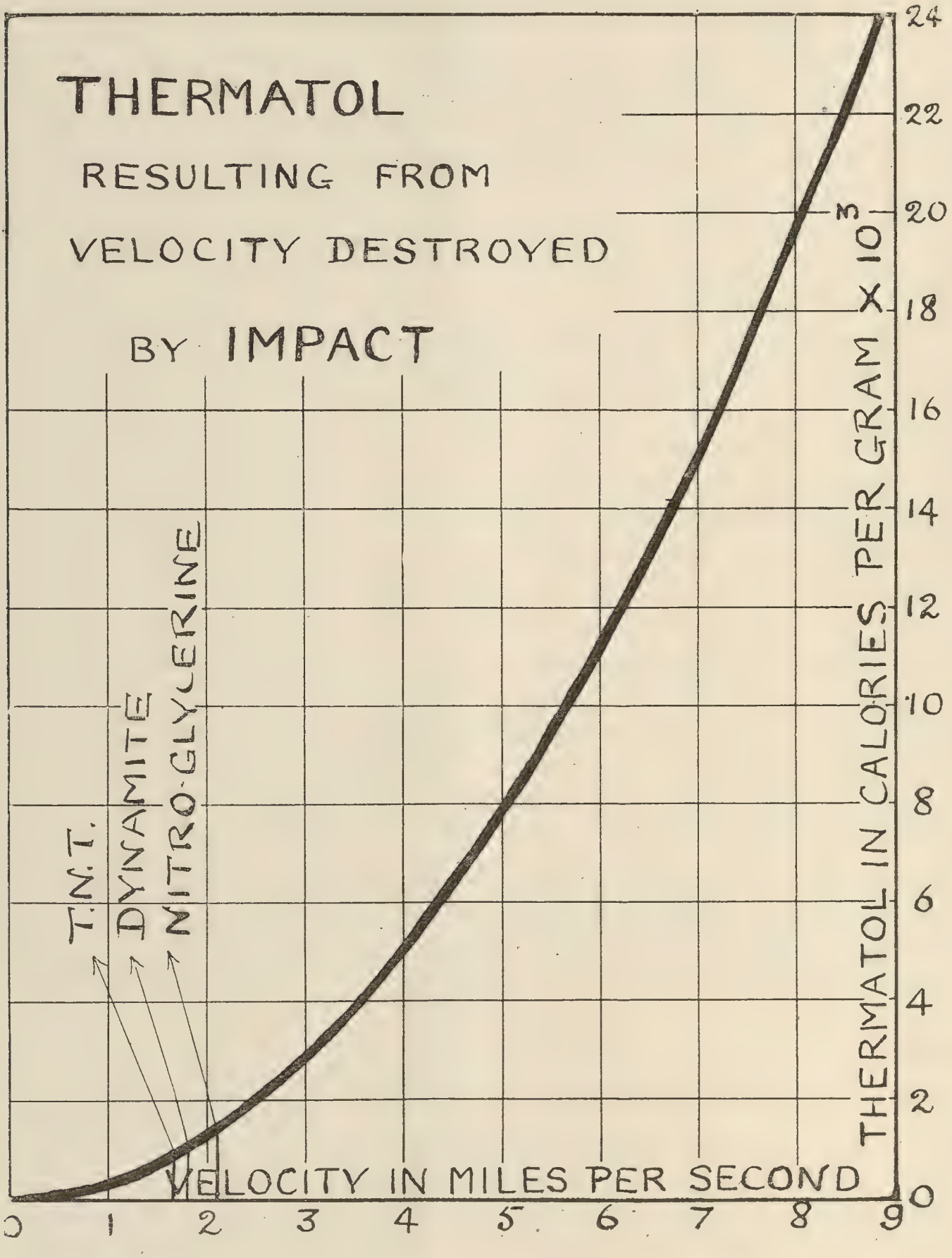

FIG. 1.—Curve showing relationship between velocity destroyed by impact and heat-energy liberated. The curve is applicable to higher velocities than those indicated if the ratio of multiplication of the thermatol scale is the square of that of the velocities; for example, if the velocities are multiplied by 10, the thermatol values must be multiplied by 100.

* It should be understood that the hypothetical resulting body twice the radius of the original bodies is gaseous, and its radius is twice that which the original bodies would have if they were gaseous. The amount of energy required to bring them to the gaseous condition is a small fraction of that liberated by the collision, and its effect on the general result is negligible.

COMPARISON OF THE THERMATOL AVAILABLE WITH THAT REQUIRED FOR COMPLETE DISSIPATION IN THE CASE OF A COLLISION OF TWO PLANETS OF PASSING STARS.

Two planets resembling	Mercury.	Venus.	Earth.	Mars.	Jupiter.	Saturn.	Uranus.	Neptune.
Thermatol I	135,388	72,530	52,465	34,420	10,085	5,500	2,734	1,745
Thermatol II	270,775	145,060	104,930	68,840	20,170	11,000	5,418	3,490
Total I and II	406,163	217,590	157,395	103,260	30,255	16,500	8,152	5,235
Equivalent velocity in miles per second ..	36	26	22	18	10	7	5	4
Orbital velocity	29	22	18	15	8	6	4	3
Maximum relative velocity of planets ..	94	70	58	48	26	19	13	10
Available thermatol corresponding to this relative velocity	2,737,000	1,518,000	1,043,000	714,200	209,600	111,900	52,390	30,980
Effective thermatol for complete dissipation ..	1,116	7,542	8,927	1,832	254,640	79,536	31,913	36,400
Ratio of available to effective thermatol ..	2,452	201	117	340	0·8	1·4	1·6	0·85

Allowing 20 miles per second relative proper motion of approach (which adds a thermatol of 123,190 calories per gramme), these numbers are modified as follows :—

Total I, II, and IV	530,109	341,500	281,305	227,170	154,165	140,410	132,063	129,145
Equivalent velocity in miles per second ..	41	33	30	27	22	21	21	20
Maximum relative velocity of planets ..	99	77	66	57	38	33	29	26
Available thermatol corresponding to this relative velocity	3,036,000	1,828,000	1,350,000	1,007,000	447,300	337,600	260,700	209,600
Ratio of available to effective thermatol ..	2,720	242	151	550	1·75	4·2	8·2	5·7

If two stars each like our Sun, with a planet exactly like Mercury accompanying each, pass at a distance of twice the radius of the orbit of Mercury, and if the planets clash into one another, the energy per unit mass can be estimated as follows :—

I. The kinetol due to the approach of the two suns to a distance twice the radius of the orbit of Mercury, $\frac{1}{2} \times 5{\cdot}4155 \times 10^5$ calories per gramme,

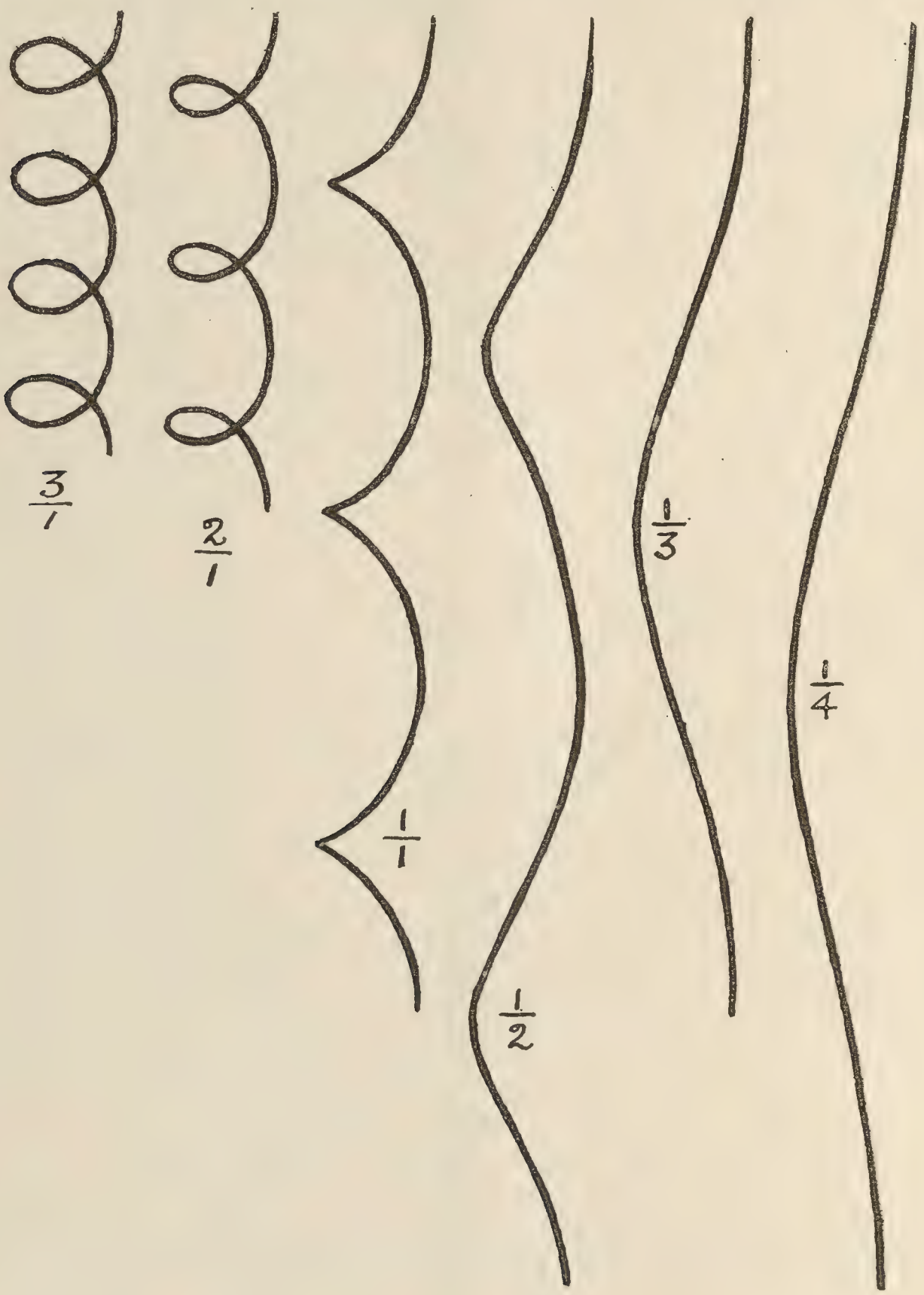

FIG. 2.—Tracks of planets or units of binary systems when the orbits lie on the same plane as the proper motion. The ratios are those of the velocities of orbital and proper motions.

is the kinetol of a particle approaching to that distance from the sun. But if two equal suns come together each acquires half only of the relative kinetol. The kinetol due to this cause is $\frac{1}{4} \times 5{\cdot}4155 \times 10^5$ calories per gramme.

II. The approach of the planet to a region of higher potential near the other star : Its distance is reduced to the radius of the orbit of Mercury. Its mass is so small ($\frac{1}{9000000}$ part of the sun's mass) that we can neglect

the approach of the sun towards it. The kinetol under heading II is $\frac{1}{2} \times 5{\cdot}4155 \times 10^5$.

A summary of the results of collisions of planets similar to those of the solar system is given in the accompanying table. The important point to notice is the ratio of the available thermatol to that required for the complete dissipation of the body formed.

These results show that collisions of planets of passing stars may differ astonishingly. Small planets like Mercury close to their parent suns would produce an impact resulting in a bright flash of short duration. The energy would in most cases be hundreds of times that required for complete dissipation, and the material would be entirely scattered through space. The initial temperature would be from tens of thousands of degrees centigrade up to more than a million. Planets like Venus and the Earth would be dissipated unless the conditions of original proper motion and the direction of orbital motion at the time of impact were very unfavourable. Planets like Mars would be generally completely scattered, on account of their small mass. Planets like Jupiter, Saturn, Uranus, or Neptune would not be dissipated unless their suns had originally considerable relative proper motion, or unless the impact was of a grazing character. The temperature produced would not usually be very high, and the phenomena could hardly be observed from stellar distance. The resulting body would be left with small velocity in space, the two suns passing on. It would therefore fall an easy prey to the first star that came near it, and would then be completely absorbed by it, causing a slight increase in brightness.

THE PATHS OF THE PLANETS BEFORE IMPACT.

If the planet is moving in a circular path round a star, whilst the system is moving uniformly in a direction perpendicular to the orbital plane, the path of the planet is a helix. Acceleration in the direction of the motion of such a system does not affect the velocity of revolution. In this case, since the two velocities are at right angles to one another, adding the energy due to motion in the orbit, so that due to motion of the system is equivalent to compounding the two velocities. If, however, the system is moving in the plane of the planets' orbit the paths of the star and planet are trochoidal curves.

The simplest case is that of a double star in which the two components are equal in mass and in which the velocity of the system is equal to the velocity of each body in its orbit round the common centre of gravity. The path of each body is then a cycloid, and when either reaches a cusp it is momentarily at rest. The velocity of each varies continually from zero up to twice the velocity of the system and back again to zero. Each body in turn possesses for a moment the entire kinetic energy of the system. It is only at the moment when both bodies are in the line of motion of the centre of gravity of the system that they have equal velocities and share the energy equally between them. If the velocity of the system is twice that of each body in its orbit, the actual velocity of each varies from once to three times the orbital velocity. Thus each body in turn accumulates in itself nine-tenths of the kinetic energy of the system. If the velocity of the system is ten times that of each in its orbit, the kinetic energy of each varies from just over 40 to just under 60 per cent. of the total energy of the system. As the velocity of the system increases the paths become straighter and the inequalities in the distribution of energy become less marked. Six of the curves are shown in fig. 2.

A BRIEF SURVEY OF RURAL CREDIT.

By J. B. CONDLIFFE, M.A., Professor of Economics, Canterbury College, and H. BELSHAW, M.A., Tutorial Class Lecturer, Canterbury College.

THE article printed below was originally prepared to be read before Section G of the Australasian Association for the Advancement of Science at its Wellington meeting in January, 1923. It attempts to describe in outline the demands of the rural industries for credit of various kinds, the organization which at present exists to meet those demands, and to estimate the present economic position in relation to certain proposals for new credit institutions.

The original paper was written in the latter months of 1922, when the rural industries were still crushed by the abnormally low level of prices that followed the collapse of the post-war boom. Its intention was to combat the notion which seemed prevalent in many quarters that the proper cure for the financial difficulties of the rural industries was the establishment of a rural bank which should make cheap credit readily available again. It will be apparent to those who read the revised article printed below that the authors clearly recognize the possibility and advisability of better organization of the facilities for granting rural credits. There is room in the Dominion for a conservative, well-managed, co-operative bank which shall relieve the farmers from the expensive and ill-organized methods at present necessary to secure long-term loans or mortgages. Such an institution, as part of the permanent financial machinery of the country, might be a valuable aid to stability. But, while this is still the opinion of the authors, as it was in 1922, they are just as strongly opposed as they were then to the notion that "cheap credit" is all that is needed to push land-values up again and restore prosperity to the rural industries. They see very grave dangers also in the establishment of "rural banks" dealing in both short- and long-term loans and doing ordinary banking business such as is undertaken by the commercial joint-stock banks at present operating.

Since this paper was first written there has been a considerable development of the "welcome revival of prices" which was noted in the text. At the worst period of the depression the prices of such raw materials and foodstuffs as form the staple exports of New Zealand were forced to unnaturally low levels by two factors which the necessities of war had superimposed upon the credit boom and crisis. There were in some products, notably wool, large accumulated stocks which at the time seemed enormous. In addition, the war had given a great stimulus to the production of agricultural products, while a large part of the manufacturing industry of Europe was destroyed. There appeared to be, therefore, a world-wide disproportion between agricultural production and manufacturing production, which was reflected in an unduly low level of prices for such goods as New Zealand exports.

In the years that have intervened that disproportion has been practically removed by a fall in the prices of manufactured goods and a

substantial rise in the prices of raw materials and foodstuffs. The price-level is now more uniform, with less dispersion among its components, than it has been since the war. This reaction has improved the economic position of New Zealand very considerably; but, in revising their description of the rural-credit problem as it existed three years ago, the authors feel that in essentials it is just as important and as true to-day as it was then. The only portion of the paper which has been considerably altered is the last section, dealing with the present economic situation and the various proposals made in the last three years for the creation of a rural bank. Except for slight alterations and statistical amendments to bring the figures quoted up to date, the rest of the paper stands as it was written in the latter part of 1922.

The problems of rural credit are of the utmost importance to a country like New Zealand, which, despite its developing secondary industries, remains essentially a well-endowed, lightly cultivated farm. The pastoral industries alone accounted in 1923 for 92·3 per cent. of the Dominion's exports (our buying-power in the markets of the world).* It is extremely important that these industries, the mainstay of our prosperity, should be economically and efficiently organized. Especially is this so at the present time, when the level of prices gives an opportunity for readjusting the heavy financial burdens carried by the primary industries. These liabilities, undertaken at a period of booming prosperity, have already proved very difficult under a lower level of prices. In the last two seasons the readjustment of raw-material values to manufactured prices, aided by the dispersion of the accumulated stocks of wool and similar commodities, have placed the primary producers in a somewhat easier condition; but there is no warrant for believing that the present upward trend of prices will continue from year to year as it did in the pre-war period. It is too soon yet to say whether the strong indications towards a lower level of prices in the long-run will be allowed to work themselves out. The gold standard has been restored throughout the British Empire, but it is too soon to say how the restoration will affect the level of prices. But there is at least the possibility—which many, but not all, eminent bankers and economists would term a probability—that for some years to come the general tendency of prices will be approximately stable, with, if anything, a gradual downward trend. The future course of prices depends upon factors which cannot yet be estimated, and largely upon decisions which have not yet been taken; but it is at least prudent to bear in mind the possibility of a gradually falling price-level through the fluctuations that are consequent upon the ebb and flow of trade in the ordinary cycle. It is this possibility which, above all, makes it imperative that the organization of our staple primary industries shall be based upon sound economic principles.

The chief problems facing the farmer at the present time are economic. Scientific knowledge, in the narrower sense of the term, is very necessary for the improvement of agricultural production; but it must be remembered that the farmer is primarily the organizer of a complex business rather than a technical expert. It is upon the business aspects of farming, and especially upon those aspects which call for social co-operation, that attention must be concentrated at the present time.

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* *New Zealand Official Year-book*, 1925, p. 278.

I. THE DEMAND FOR CREDIT.

(a.) The Complex of Rural Industries.

The farming industries of New Zealand are not a single simple business, but form an industrial complex of many types of production. The problem of rural credit, therefore, is not merely a problem of providing capital for a single purpose to a simply organized industry working under static and uniform conditions. In a sense each farm is a business of its own peculiar type, but it is possible to make a rough classification into dairying, sheep-farming, mixed farming (including cereal-growing). The possible variations of these types are, however, very great. It is the exception rather than the rule to find a farm devoted exclusively to one purpose. Even where dairy farms are specialized, supplying milk or cream to the co-operative factory, and either selling their by-products for the manufacture of casein or sugar of milk or using them for pig-rearing, there is still room for variation in the use of dual- or single-purpose cows, and in the breeding of pedigree stock as a side line. The specialized cereal farm is practically non-existent. Land must have a rest from cereal crops, so that not only must rotation be practised, but some form of stock must be kept to utilize roughage and help manure the land. So all sorts of mixed farms are possible. Where specialized sheep-farms exist we find some which rear and sell but do not fatten store sheep; others which both rear and fatten; and others which purchase and fatten but do not rear (and therefore need not winter) many sheep or cattle.

There are possible, therefore, almost innumerable variations not only by different combinations of the three main types of farming, but also by all sorts of differences of practice. These differences are of more than superficial importance, since they lead to a great variety of industrial structure, and therefore to many different kinds of relationships among farmers themselves, between farmers and middlemen, farmers and manufacturers, farmers and consumers. The result is that the financial organization varies practically from farm to farm.

(b.) The Capital Requirements of Farms.

Like every other modern industry, farming demands for its efficient prosecution a great amount of capital goods. On some old-established farms this capital is provided literally out of the proceeds of past production—the improvements, buildings, fences, pastures, the very soil and the machinery to work it, have come from the surplus produced by the farmer's labour. But the number of such farms in New Zealand must be relatively few. Not many farms are unencumbered. Even if the land is absolutely the property of the farmer, there is likely to be some mortgage or lien of a temporary or permanent nature to provide stock, machinery, or running-expenses. The great majority of farmers provide much—in many cases too much—of their capital by borrowing it, either upon the security of the land itself, or the stock, or what in many cases amounts to personal security buttressed by these other forms. In the extreme cases—which are, unfortunately, only too common—the farmer becomes little more than a working manager for his financial backers. His equity in the land is very small. For his extra capital, his working-expenses, and in many cases his household expenses, he must depend upon advances from them; and in times of difficulty he may even be hampered by their interference in his management.

The problem of rural credit, therefore, resolves itself into the problem of providing capital for the various requirements of a complex industry. There are five main purposes for which capital is required in farming: (1) For the purchase of land and improvements; (2) for implements and the effecting of further improvements; (3) for the purchase of stock; (2) for the provision of labour at exceptional periods, such as harvest or shearing time; (5) for cash to run the farm.

It will be seen at once that the demand for capital is composite, and made up of demands which vary greatly, especially in the degree of permanence or fixation of the capital goods required, and therefore in the term for which the loan must be raised. As in all businesses, there is a rough distinction between fixed and circulating capital—the former being supplied by more definite and rigid forms of loan, corresponding to share capital, or more strictly to debentures; the latter being supplied from more liquid sources of credit, corresponding to overdrafts. The chief difference between the financial structure of farming and of urban industries lies in the fact that, as a rule, the farmer supplies a much smaller proportion of his fixed capital and works very largely upon mortgages, corresponding to debentures. His position is analogous to that of the small storekeeper whose premises as well as whose stocks are often mortgaged to a wholesale firm, and who is in consequence tied to that firm.

Roughly, we may say that for the first two purposes mentioned above, the purchase of land, implements, and improvements, loans must be definite and fixed for a considerable term. For the last two purposes the farmers' demands are more capricious, and the credit is required for shorter terms and in smaller amounts. The credit required for the purchase of stock may fall into either class. The purchase of stock may sometimes be analogous to the purchase of machinery—the addition of instrumental capital to the farm; in other cases it is more like the addition of stock-in-trade to the merchant's shelves. In the case of most small farmers the land is stocked by an advance from a commercial firm, and any speculation in stock for which an additional credit is required for a short period is financed by an extension of the original advance.

The distinction just made is one of great practical importance in determining not only the readiness with which capital may be obtained, but also the manner in which the loans are raised, the length of term, the manner of repayment, &c. From the practical point of view the two chief factors to be considered in any loan are the security offered and the rapidity and certainty of repayment. These are the factors which determine the readiness of the lenders to grant credit facilities, and determine also the rate of interest charged. It will be realized that every loan has to be scrutinized most carefully, and usually involves a consideration of the whole financial position of the farmer.

Enough has been said to show the composite nature of the demand for credit, and especially to bring out the main cleavage (which is, of course, not clean-cut) between semi-permanent, secured loans and temporary advances which, although secured, depend more upon the personality of the farmer in question. The first type belongs rather to the productive side of farming, the second to the commercial or speculative side.

(c.) The Distribution of Capital on New Zealand Farms.

Almost as important as the total amount of capital required on a farm is the distribution of that amount over the various farm requirements. A type of farming which uses land of a high value compared with the other

agents of production, which gives rapid, continuous, and certain returns to effort, produces a commodity for which there is a steady demand, and therefore possessing a steady value, will most readily obtain credit.

There are three main influences determining the amount and distribution of the capital required on farms. These are—

1. *Individual Peculiarities of Farms and Farmers.*—The peculiarities of soil or situation of the land itself, and the capability and character of the farmer, are the first points to be considered. After all, the loan is a personal transaction, and everything depends upon the character of the borrower.

2. *Size of Holding.*—As in all businesses, there tends to develop a "most economical size" of farm. Small farms show a heavier expenditure of labour and capital per acre; but there is a definite lower limit of size set by the unit of working-implements, usually the team of horses. The farm, like other businesses, must keep its working-machinery fully and adequately employed all the year round. Unless returns are adequate to meet the heavy interest, depreciation, and maintenance charges, these overhead expenses eat up all the product of the farmer's labour. The result is only too often seen in his becoming tied to an agency company. The size of farm that has tended to develop in New Zealand is the smallest that could reasonably be expected to provide adequate employment for a unit of working-stock and implements. Where, as in the case of dairying, skilled and reliable labour is required, the size is that which provides employment for a family unit of labour. The area is naturally smaller in the case of dairy farms than in mixed farming.

3. *The Type of Farming.*—The proportion of capital expenditure required under the various headings noted above—land, implements, stock, labour, current expenses—naturally varies with the type of farming, a fact which has important practical results in the development of one type of farming as compared with another according to the ease with which credit may be secured for various uses. It is obviously impossible to do more than generalize concerning the proportions of capital required in different directions on the main types of farm; but the statements made below have been checked by experienced and practical farmers.

Generally speaking, dairying is more attractive and easier of access to the settler with moderate capital. The most noticeable feature of economic development in New Zealand during the last thirty years has been the rapid and continuous development of dairying. The prime reason for this was the impetus given by refrigeration, which meant more to dairying than it did to sheep-grazing, and still more than to cereal-growing. It must be added that the Dominion has one of the best climates in the world for dairying, and wonderful pastures, and that the demand for dairy-produce in the markets of the world has been steady and keen.

But, in addition to these powerful factors, there are special reasons connected with the financing of dairy farms that make them specially attractive to the small settler. Though the price paid for dairying-land is usually higher than that for other types of farming, the area is so much smaller that the outlay on the land itself is less. The wise settler prefers a comparatively small farm with adequate working capital rather than a large area with restricted finance. The regularity of the monthly butter-fat cheque provides a constant source of income, and makes accounting easier and more certain. The regularity of returns also makes it possible to pay any wages for hired labour from current income. In the other types of farming the expenditure on harvesting, shearing, &c., must be made

just before the main returns of the year come in, and must therefore be met, as a rule, by temporary borrowing upon the security of the wool or harvest. The demand for hired labour in dairying, however, is very small. On nine farms investigated by Mr. Belshaw in 1919–20 it was calculated that 93·2 per cent. of the labour was provided by the farmer and his own family, 5·1 per cent. by permanent hired labour, and 1·7 per cent. by casual labour.*

In the purchase of stock, again, there is an important difference between dairying and other types of farming. Dairy farms approximate more to the true type of productive farming, whereas there is a far larger element of speculation and trading in sheep-farming particularly. On most dairy farms the cows are to be regarded as living machines for the production of butter, cheese, &c. The initial cost of stock is heavy, but there is little speculative buying and selling. The credit necessary to stock up the farm is therefore usually of the same nature as that advanced for the purchase of the land. In fact, it is the custom for the agency company negotiating the purchase of a property to finance the buyer both in respect of his land and his stock.

Similarly, there is less need on the specialized dairy farm for expensive implements. The investigation previously mentioned showed that on nine dairy farms 77 per cent. of the area was in pasture, 7·7 per cent. in unploughable land, 7·2 per cent. in hay or ensilage, 2·3 per cent. in forage crops, and 5·8 per cent. in root crops. The specialized dairy farm will keep a two-horse team, a single- or double-furrow plough, a mower, and one or two other implements of small size and simple construction. Mixed farms and sheep-farms will seldom have less than a six-horse team—probably two or three of them—with more expensive and complicated implements.* This means not only a bigger overdraft to provide working plant on such farms, but also heavier outgoings in the shape of current working-expenses. On a dairy farm the working-expenses are low and regular. Even if the farm possesses a milking plant, the expenditure, both on the initial installation and for oil, &c., is less than the cost of providing and maintaining horses and implements on a mixed farm.†

As a general rule it may be said, therefore, that the absolute amount of capital required on a dairy farm is lower than in other types of farming, and that a larger proportion of it is of the more permanent fixed type.

II. Existing Facilities for Rural Credit.

Attention has been directed to the varied nature of the demand for capital in rural enterprises. It should be stated that the overwhelming majority of small farms in New Zealand are freehold, and therefore the demand for rural credit is almost universal. The total area of occupied land in New Zealand is $43\frac{1}{2}$ million acres, of which 20 millions are freehold occupied by the owner; $2\frac{3}{4}$ million acres are leased privately or from public bodies, $1\frac{1}{2}$ million from the Natives. Though over 19 million acres remain Crown leasehold of various types, by far the largest part of this area is made up of pastoral sheep-country which, to be profitable, must be held in large runs. The small farmers of the Dominion work on freehold land.‡

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* Belshaw, *The Dairying Industry in New Zealand*, (M.A. thesis).

† See Fawcett, *Journal of Agriculture*, Dec., 1923, for an estimate of the cost of maintaining a six-horse team.

‡ *New Zealand Official Year-book*, 1925, p. 377.

There is no settled farming community. Owing to the land-transfer system, the sale and exchange of farms is readily undertaken, so that there is a very considerable speculative element not only in the sale of stock but in the sale of the land itself. This has been particularly true of the period of prosperity based on rising prices from 1895 to 1920. The problem of rural credit is therefore of far more importance than it usually is in rural industries, and credit is just as much the life of farming as it is of business generally.

(a.) Purchasing a Farm.

A settler desirous of taking up land, in all but a rare minority of cases, works through a land agent or the land-agency department of an agency company. The ease with which land may be transferred has led to a multiplicity of such land-dealers, and there is the keenest competition among them for the substantial commissions which are drawn from sales or exchanges. The existence of so many competing agencies, each with its equipment of salesmen and their cars, is not only a constant incitement to farmers to farm for the property-market, but is also a heavy charge upon the man who is actually working the land.

A more important result of the competition between land-dealers is that, in order to gain the tempting commission, they are practically forced into financing prospective purchasers. The result has been, especially in the boom period just ended, that settlers have been assisted into farming enterprises the financial organization of which would have been impossible in almost any other business. The minimum of capital was necessary, especially in exchanges of one farm for another. Not only the bulk of the purchase-money for the land, but the credit required for stock, implements, current expenses, even household expenses, was readily available by the firm which was prepared to " see the settler through " or " carry him on."

Not the least difficult problem that arose as soon as the boom had burst centred around the farmers who had been tempted by the artificial prices into selling their moderate holdings and using the proceeds as a means to obtain larger farms also at artificial prices. In many cases the usual custom was followed of leaving a good proportion of the selling-price of the farm as a second or third or later mortgage, so that in many districts there is a veritable tangle of mortgagees and mortgagors. The artificiality of the situation was quickly revealed at the first depression of prices, but the readjustment of valuations and mortgages remains the first requisite step towards a more normal organization of rural industries.

It will be evident that a great part of the fixed capital required in farming is provided either by the sellers who leave some of the purchase-money on a late and risky mortgage, or by the land agencies, to whose interest it is that as many properties as possible shall change hands at the highest possible price.

(b.) Share Farming.

An important variation in the method of acquiring land by receiving credit from private individuals or businesses is the method, particularly useful in the dairying industry, of farming on shares. In its essentials this system resembles the European *métayage*, but it has been developed to suit the particular needs of New Zealand. In a typical share-milking agreement an agreed proportion of the returns from milk and other sources is paid to the share milker, who agrees to do all the work on the farm. One-third of the labour of providing winter feed is borne by him, the rest by

the owner of the land and stock. The agreements are, however, by no means stereotyped in form, and the actual division of labour and of returns is the result of bargaining by the parties concerned.

The wide acceptance of this arrangement shows that it has satisfied a real need. To the owner it provides a means of cultivating his land; to the tenant a ready means of obtaining land and stock. It is not contended that farms held on this tenure are run as well as freehold farms. The share milker receives only a portion of the fruits of his extra labour. From the owner's point of view the main difficulty is that, since the agreements are usually annual, they directly encourage predatory methods of farming. This involves supervision by the farmer, but, even so, it is better than working the farm under a manager, since the system of profit-sharing is an incentive to effort.

With all its difficulties and disadvantages share milking has much to recommend it. Often enough a compulsory purchasing clause is inserted in the agreement for the benefit of the share milker, who may, therefore, obtain land and stock with a minimum of capital. He is protected from foreclosure and eviction in a bad season, and his success, given an equitable agreement, depends mainly upon his own industry and enterprise. There are many wealthy farmers in Taranaki to-day who began as share milkers, and whose capital at one time consisted almost solely of their industry and ability to farm. They have had, it is true, favouring, prosperous conditions. Whether the system will stand the test of a period of adversity is still to be seen.

(c.) State Assistance.

The Dominion Government assists small farmers to acquire land indirectly by taxation designed to burst up large holdings,* and directly by the purchase, subdivision, and leasing of land, and also by the advancing of credit to farmers who have bought freehold land. The provision of leasehold land obviates the necessity of the farmer sinking a large capital in acquiring the land, and therefore acts as a direct relief to the demand for capital. To embark upon a full description of the system of Crown leaseholds would take us too far away from our subject. The material is readily available in the Official Year-book.†

The most important way in which the Government directly advances credit is through the operations of the Advances to Settlers Department, which uses the loans specifically raised for advances, reinvests its own sinking funds, and also portions of the public-debt sinking funds. The Act was passed in 1894, and since that time the total advances authorized up to the 31st March, 1924, have been over 27½ millions. The total amount of advances current at that date was just over eleven millions, owed by over twenty thousand settlers. A large proportion of this, however, is advanced on urban lands, so that the number of advances on rural lands is only 12,286, amounting to £5,766,139. The average sum advanced is £469, and the great bulk of the advances are made on freehold farms.‡

From these figures it will be evident that the money-lending of this Government Department is confined to the advance of comparatively

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* Since the repeal of the income-tax upon farmers in 1923, the land-tax is merely a substitute for income-tax and not a penal addition to it. Its effect in bursting up large estates at the present time is negative.

† *New Zealand Official Year-book*, 1915.

‡ *New Zealand Official Year-book*, 1925, pp. 583–84.

small sums to assist in the purchase of the land itself. The loans are advanced against first mortgages, so that it is only upon the best security that the Government makes a limited advance. The bulk of the problem of rural credit, and nearly all of its difficulties, lie outside the sphere of the State enterprise. All the risky advances of the remaining capital to purchase the land, all advances for implements, stock, &c., must be obtained elsewhere.

An exception to this general statement may be made in the case of the financial assistance given to returned soldiers to establish themselves on farms. The most liberal assistance was given by the Government, not only in the purchase of land but also for stock and implements. This liberality towards the returned soldier was undoubtedly one of the contributing causes to the boom in land-values after the war. Many hundreds of new settlers were loosed in the market with very liberal credit, so that the price of land was forced up. The total amount advanced up to the 31st March, 1924, was £21,863,500, to 22,213 settlers. Of this amount, over 13¼ millions was advanced to 10,343 settlers on rural land.*

(d.) Dealers' Credit.

In most districts the bulk of the credit required by the rural industries is supplied by commercial houses called "agency companies" or "stock and station agents." The names recall their origin in the service they were able to render the sheep-farming industry in the early days of Australia and New Zealand. They are primarily dealers not only in stock but also in farm requirements. They buy the farmer's products, and sell implements, materials, seeds, manures, and practically all farm and domestic requisites.

A natural extension and aid to this main function has been the development of a banking side to the business in order to loan credit to farmers. It is perhaps inevitable that the more temporary loans shall develop out of extended credit for the purchase of requisites and advances against sales of produce. The competition between these firms has gone very far not only in this direction, but also in the advancing of credit for the more permanent working-capital which is locked up in land and implements.

The credit advanced to the farmers is obtained partly from the banks at current rates of interest, and reloaned at a slightly higher rate which just about compensates for administrative expenses and risk. Many of the firms, however, act also as deposit bankers for their clients, accepting both current and fixed deposits and allowing cheques to be drawn on the former. In this way they build up large funds available for investment in mortgages. The joint-stock banks proper in New Zealand do not give interest on current accounts, and the substantial interest offered by the agency firms is an inducement to many people to allow their current accounts to lie with them. The deposit banking naturally merges into the other section of the business by which farmers are allowed overdrafts secured by mortgages and liens of various kinds.

In times of credit stringency these operations may prove a source of considerable embarrassment to the banking institutions of the Dominion. During the recent depression special legislation had to be passed to protect the agency companies from the possibility of a run by the depositors. In

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* *New Zealand Official Year-book*, 1925, p. 392. (Note.—It was necessary in the session of 1923 to pass an Act reducing the capital value of many of these soldier farms.)

times of boom, such as the years 1918–20, the keen competition between these firms results in the ready financing of every settler, so that very large amounts of credit are issued, which in times of difficulty swell the overdrafts of the agency firms with the banks and prove a source of great difficulty to the latter when the depression in prices causes the advances to become frozen.

Reference has been made to the undesirable connection between commissions to be gained on the sale or exchange of land and the advancing of credit to prospective settlers. The same argument holds concerning the commissions received for the sale of stock, &c., and the profits made on the merchandise sold to farmer clients. A farmer becomes tied to a certain firm : his only means of obtaining the credit necessary to buy extra stock or seeds or implements, to employ labour for harvesting, threshing, or shearing, even to pay his household expenses, is to draw a cheque on his already overdrawn account. It is usually a condition of his advance that he must sell his produce through the auctioneering department of his financial backers, or else pay them their commission. He is therefore considerably hampered in not being able to buy or sell just when and where he pleases. His dependence does not stop at being tied in respect of his purchases and sales to a single middleman, but in times of depression he may have to suffer interference with the detailed work of his management. This cannot but result in the long-run in inefficiency, and it is only one aspect of the difficulty into which the too free use of credit has landed the farming community.

Most of these firms are of such a size that they pay income-tax (leviable in New Zealand upon companies) at the maximum rate. Each of their departments has to compete with smaller specialized concerns paying lower rates. There seems little doubt that the prosperity of the agency firms as a whole depends upon the extent to which they can make the farmer financially dependent upon them. In other countries this form of dealer's credit has been attended with serious abuses. Wolff, the great authority on rural credit, writing in *People's Banks* (pp. 63–64), sums up these evils : "You may say that farmers do not want credit—that it is too dear for them. Farmers show that they do want it by practising it in the wrong way and in the dearest possible form. Reckon up what it costs in higher price, in inferior quality of goods, in dependence upon your dealer in your purchase, and you will find the cost totalling up to a considerable figure. . . . I do not know if the dependence, sometimes amounting almost to peonage, the sacrifice of freedom of action, may not be taken to rank as the heaviest item of the account."

It must be clear that the development of New Zealand has been greatly influenced by and dependent upon the agency companies. The rapid and continuous development of the Dominion could hardly have been possible without the ready credit which they made available. They were built up in a period when sheep and mixed farming predominated in the Dominion, and their business lends itself to the financing of speculative farming. Where the more stable dairying is carried on to a great extent, as in Taranaki, new forms of credit agencies develop. In dairying the product of the farm goes direct to the co-operative factory ; there is little commission to be gained, and therefore the rate of interest charged by agency companies on advances is often higher.

It is at least arguable whether the agency firms have not been too liberal to the farmer for his own good—whether the real development of the Dominion has not been retarded by the forced speculative development.

During the long period of prosperity from 1895 to 1920, when each year's prices were higher than the last, and the current term used to describe the Dominion's prosperity was "buoyant," they tended to forget the lessons of the period of adversity and falling prices through which New Zealand struggled from 1873 to 1895. It is quite clear that they must bear their share of responsibility for feeding the post-war boom in their anxiety to secure as large a share of the spoils, such as land-agency commissions, as was possible. At the present time it is common knowledge that many of them, especially the quasi-co-operative concerns, are suffering heavily from the 1920–22 depression. To rash speculative advances were added in many cases heavy importation and over-expansion generally. Appeal has had to be made in many cases to the public for a sort of funding of liabilities by issuing ten-year debentures at from 7½ to 10 per cent. for large amounts. Even this postponement of the evil day has hardly sufficed to lift the burden, though the banks proper have arranged extra support, and the Government at one time contemplated similar action.*

Perhaps the most disquieting feature of the whole situation is that after twenty-five years of continuous prosperity, including the very prosperous war period and the post-war boom, these firms upon whom so much depends should be so hard hit by the first gust of adversity. It would seem that, both in respect of their individual businesses and in their financial control over the primary industries of the Dominion, they have relied upon a continuance of the easy prosperity that, in a country like New Zealand, which is both producer and debtor, always attends a rising level of prices. The lack of reserves and the over-optimistic capitalization of the main producing businesses of the Dominion, involving not only the agency companies but through them the banks and indirectly the whole community, cannot but give cause for anxiety if, as seems likely, the era of rising prices is definitely past, and a decade of lower and possibly falling prices confronts the Dominion.

(e.) Finance and Loan Companies.

In the more stable dairying industry, especially in Taranaki, there have developed finance and loan companies which act as intermediaries between the banks and the farmers. Their position is worth noting, since they are doing exactly what a rural co-operative credit association might do. Their success in a limited sphere is an indication both of the advantages and the narrow limits which might attend the proposed co-operative bodies.

"Six men with capital form a company, putting £500 each into the venture. On each £3,000 made up the bank will advance £2 for £1, or £6,000. The six members sign a joint and several guarantee for the £6,000. The £9,000 is then lent on cows, or land, or both—sometimes on a bill of sale over stock, or on a mortgage over land, or on a guarantee—and this security is deposited with the bank as well. The borrower has to reduce the amount by one-third or one-half of every monthly milk-cheque, which he assigns until the loan is repaid. Interest is charged at the rate of from 7 to 9 per cent., and if the company gets 8 per cent. on

* The shares of these companies were for some time practically unsaleable, and still are at a very low figure. The bonds referred to above are also at a considerable discount in most cases, while arrangements have been made in some instances to reduce the original rate of interest payable and also to call up fresh capital from the shareholders.

the bank money for which it pays 6 per cent., then a safe and profitable business is the result. Speaking generally, these institutions act as small banks, taking risks in making advances which the banks do not care about."*

There are at present seven such institutions operating in south Taranaki. One of these is financing sixty farms and lending over £82,000. Their operations, however, are confined to a limited number of dairy farms where returns are regular and security is good. They form a very useful link between the bank and the farmer, and the "extra risk which the banks do not care about" is probably eliminated by the closer knowledge of farm affairs and the better opportunity of testing a man's personal capacity to run a farm. It is probable that they exercise a selective influence in picking out capable farmers who would otherwise be hindered by lack of capital.

(f.) Banks.

Speaking broadly, the joint-stock banks operating in New Zealand do not directly finance farm operations either by the provision of fixed capital or by the granting of overdrafts for circulating capital. There are cases in which both of these forms of advances are given, and there are other cases in which such securities may recoil, perhaps in great amounts, upon the banks in a time of prolonged depression. The difficult banking crisis of 1893 was in fact caused in this way. The business of banking requires that assets should be readily realizable—"liquid," in the common phrase. Mortgages on farm property can hardly be said to form liquid security, and in times of difficulty farm credits are perhaps more likely to become frozen than any other advances. The farmer is less able than most other business men to raise any ready cash in an emergency. It follows that the majority of farmers, especially the small men, must derive their credit from other agencies, which in turn lean on the banks.

It will be clear, however, that the banks exercise a very real control over the whole issue of rural credit in the Dominion, none the less real because it is mainly indirect. Land agents, private individuals, finance companies, agency companies, and to some extent the State, lean upon the banks for the credit they relend to the farmers.

Like the agency companies—and, indeed, most businesses in New Zealand—the banks have enjoyed steady and buoyant prosperity in the Dominion every since their recovery a few years after the failures and difficulties of 1893. The banks also must bear their share of responsibility for the post-war boom, which depended in the main upon credit inflation. It is idle now to indulge in recrimination concerning the blame for that orgy of inflation and gambling, but it is obvious that the land-dealers, merchants, and agency companies who fed the boom could have been checked in their operation by a restriction on their credit such as a substantial rise in the rate of interest charged on overdraft. After the boom burst the mischief was done. It was then too late to repair the damage by raising the rate.

It is true that all sections of the community indulged in the scramble to get rich quickly; but that does not absolve the banks from their responsibility. In their hands, to a great and increasing extent, lie the economic issues before the Dominion. Their responsibility is plainer when the history of New Zealand teaches such plain lessons concerning the results of extravagant borrowing, inflation of credit, and land-values. The

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* POWDRELL, *Dairy-farming in New Zealand*, p. 11.

long depression of the "seventies" and "eighties" was directly due to just such another boom; but the public memory is short and the economic history of the Dominion little known.

III. THE PRESENT ECONOMIC SITUATION.

During the twenty-five years from 1895 to 1920 New Zealand enjoyed almost continuous prosperity. The present generation can hardly realize a time when prices were not rising and prosperity general. During the whole of that period credit has been easy and cheap, both for the Government and for business enterprises. Development has been rapid and continuous, and values have consistently appreciated. There is a natural tendency always for speculative activity to anticipate future rises in prices and land-values, so that at any particular time it is probable that the value of land is such as to make it unremunerative as compared with the prices of its products at that time.* The majority of farmers have been content to pay such prices for land that they have been forced to work hard for a number of years for small remuneration, and have waited their chance to sell out at enhanced values and so accumulate a capitalized profit. During the war the prices of farm-products rose, but the boom did not set in until after 1918. Both governmental and private expenditure was kept within limits until the post-war boom. During the boom period, however, very heavy overhead liabilities were piled up. Governmental expenditure, which had increased from £11,000,000 to £15,000,000 between 1913 and 1918, jumped up to £28,000,000 in 1922.† The public debt, already swollen by the whole cost of the War Expenses Account, was further increased by heavy borrowing. At the end of the financial year 1914 the net public debt was less than £92,000,000, by 1918 it was nearly £146,000,000, and in 1922 over £208,000,000. The bearing of this on the problem of rural credit is through the taxation which is involved by the increase of expenditure and debt charges.‡

At the same time the boom in land-values has caused a serious over-valuation of the rural industries, as was described above. The remedy, therefore, does not lie in the provision of schemes for more and cheaper credit. The over-valuation, added to heavy taxation and high wages, has clearly placed many farmers in sore need of credit at the moment. Their resources are tied up in uneconomical directions, particularly in the heavy interest they must pay on excessive mortgages, and in taxation. The solution of the problem, however, does not lie in providing further credit

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* See for examples of this the evidence given by dairy-farmers before the Committee which inquired into the price of butter during the boom. Though butterfat was 2s. 6d. per pound it was conclusively shown that with land-values at the level then ruling the business of farming was not remunerative.

† Reduced by the 31st March, 1924, to £26,000,000 (*New Zealand Official Year-book*, 1925, p. 535).

‡ The public debt stood at the 31st March, 1924, at £208,595,743; but as a result of the financial operations of the last two or three years an appreciably larger proportion of it is now held overseas. Though the total debt has not increased, the annual interest payable has increased heavily, as the following short table shows :—

	Net Debt (Millions). £	Interest. £
1914	92	2·9
1918	146	4·4
1922	208	8·4
1923	209	8·9

to enable unprofitable enterprises to continue longer in a time of much lower prices. Still less do we want to take advantage of the present natural reaction from the unnaturally low level of prices of the panic stage of the crisis to begin another little boom based on either borrowing or inflated credit within the Dominion. On the other hand, advantage should be taken of this breathing-space to readjust the financial organization of the rural industries before the general tendency to a lower and probably falling post-war level of prices reasserts itself. It is not our intention to discuss the factors which make us sceptical of any immediate return to pre-war prosperity. The present situation in Europe is sufficient to assure any one who takes a long view that the return of easy credit, rising prices, and steady demand for our products is not yet in sight, despite the upward movement of prices in the last two years. With such a prospect the heavy liabilities we have discussed may well give food for anxious thought.

The higher price-levels ruling in the last year or two have relieved the economic situation in New Zealand very considerably; but their effect has been mainly in reducing the short-term advances to more manageable amounts. They cannot have done very much to adjust the long-term debt and mortgage problems. The Government Statistician calculates each year the effect of the higher or lower prices received for our exports, and this calculation throws a good deal of light upon the problems of rural credit. The short table below is adapted from the calculation published in the last *Official Year-book*.

*Exports of New Zealand Produce.**

Year.	Recorded Value (Millions).		Value at 1900 Prices (Millions).	
	Total.	Per Head.	Total.	Per Head.
	£	£	£	£
1918	27·9	24·2	12·4	10·8
1919	53·3	44·7	24·8	20·8
1920	45·6	36·7	20·0	16·2
1921	43·6	34·2	21·3	16·7
1922	41·7	31·2	27·0	20·7
1923	45·4	34·2	23·9	18·0

A comparison of these figures shows that at 1900 prices the average value of exports in the five years 1900–4 was £16·8, while the similar figure for the six years 1918–23 was £17·2. It is evident, therefore, that the actual productivity of the Dominion per head of population has not increased very greatly in twenty years. Our recent prosperity, in other words, is based almost wholly upon the rising price-level, which in 1923 gave us a total of £45,000,000 for exports which in 1900 would have brought only £24,000,000.

A simple calculation from the same table shows that if 1918 values are taken as base = 100, the movements of export prices, calculated from

* *New Zealand Official Year-book*, 1925, pp. 299–300.

and weighted according to the actual export quantities and values of each item, are as follows :—

1918	100	1921	91
1919	96	1922	68
1920	102*	1923	84

The recovery of recent years has therefore still some way to go before it can approximate to the boom price-levels for all classes of New Zealand produce. The statistics for 1924 and 1925 will no doubt show a much greater improvement because of the enhanced prices ruling for meat and wool; but this improvement must be set against the three lean years immediately preceding.

If the Government Statistician's chain-index be taken, calculated for each year upon the basis of the previous year's prices, the same result is shown in a slightly different way :—

Exports of New Zealand Produce.†

Year.	Total Exports (Millions).		Effect of Price-changes (Millions).	
	Recorded.	At Previous Year's Prices.	Gain.	Loss.
	£	£	£	£
1919	53·3	55·9	..	2·6
1920	45·6	43·1	2·5	..
1921	43·6	48·4	..	4·8
1922	41·7	55·3	..	13·6
1923	45·4	37·0	8·4	..

The gains in 1924 and 1925 should be substantial, putting up the total values of exports to levels approaching that of 1919, and even surpassing it in 1925. The chief benefit of these enhanced prices, however, will be in compensating for the losses made by farmers in the bad years preceding. The first call upon them will be for the reduction of the advances made by the loan and agency companies to their farmer clients, and these advances will probably be got down to manageable proportions.

The effect of the higher prices in reducing the more permanent mortgages as distinct from the short-term advances cannot be very great in proportion to the magnitude of the amounts outstanding. Some readjustment has been made already by mutual consent of mortgagees and mortgagors, the Government having led the way by concessions to soldier settlers. It is to be hoped that many farmers will take the advice of the present Minister of Lands and use as much of their receipts as possible to pay off part of the mortgage. But in the aggregate the mortgage problem still remains very difficult, and will still be dangerous if there should happen to come a fall in prices. This will be readily seen when the available statistics of mortgages outstanding are compared with the figures quoted above.

* Rise due to greater export of dairy-produce, then at the peak of butterfat prices.

† *New Zealand Official Year-book*, 1925, pp. 299–300.

*Mortgages registered and discharged.**

Year.	Mortgages registered (Millions).	Mortgages discharged (Millions).	Mortgages outstanding (Millions).	Average Rate of Interest per Cent.
	£	£	£	
1918–19 ..	19·0	11·0	146·7	5·8
1919–20 ..	48·4	23·1	172·1	5·8
1920–21 ..	67·0	29·5	209·6	6·1
1921–22 ..	34·8	13·2	231·1	6·4
1922–23 ..	26·0	14·6	242·6	6·6
1923–24 ..	37·9	22·2	258·2	6·4

These figures, though official and the only statistics available, do not accurately represent the true position. Some mortgages are never registered, and probably a greater proportion are never formally discharged. The amount of mortgages outstanding is therefore probably exaggerated to a considerable extent. The only estimate of which the authors know that attempts to estimate the actual total of rural mortgages which are really "live" at the present time is one which was made, after consultation with the Treasury, by a prominent merchant engaged in loan and agency business. This estimate placed the outstanding rural mortgages as about £136,000,000. But even this much lower figure is big enough to show that the recent gains from higher export prices, after the temporary advances have been reduced, cannot have done much to ease the mortgage situation, except that they make the payment of current interest a good deal easier.

New Zealand is living right up to, if not over, its income. The high volume of imports in proportion to exports is evidence of this fact.†

* *New Zealand Official Year-book*, 1925, pp. 684–91.

† The proportion of imports to exports in recent years is shown by the following table:—

Year.	Imports (Millions).	Exports (Millions).	Proportion of Imports to Exports.
	£	£	Per Cent.
1918	24·2	28·5	85
1919	30·7	54·0	56
1920	61·6	46·4	133
1921	42·9	44·8	96
1922	35·0	42·7	82
1923	43·4	46·0	94

The average excess of exports in the six years 1918–23 is therefore 4·3 million pounds, and if the figures for 1924 were taken the average would be less. The interest on the public and local-body debt held overseas is given by the Government Statistician as 5·2 millions, to which must be added an adverse balance of freight charges, officially calculated at approximately 4 millions, and also interest upon private capital invested in the Dominion. It is evident, therefore, that the average excess of exports is less than half the amount necessary to square our balance of indebtedness, and that the balance is being met by fresh Government and local-body borrowings and by fresh investments of private capital in New Zealand. (See *Official Year-book*, 1925, pp. 271–72.)

A sharp fall in export prices such as occurred in the slump period, or even a gradual fall in the general price-level such as many authorities consider possible, would lead the Dominion once again into serious difficulties. We are really gambling upon a continuance of the present price-levels.

There is always a natural tendency for farmers—and, indeed, for all classes of traders and producers—to demand cheap credit and to press for policies which make for rising price-levels. This tendency is well recognized by economists the world over. It is particularly clear among the farming community of the United States of America, where it has taken various forms, from the agitation for free coinage of silver in the last period of falling prices to the rural-credit agitation of the present day.* It is inevitable that those who have committed themselves to contracts that depend for their profit upon a maintenance of high price-levels shall support credit and currency policies designed to keep prices up. There is a natural reluctance to cut losses and bring values down to lower levels.

But it would be unwise, we believe, for the farmers of New Zealand to create a network of co-operative banks if they are so designed as merely to add to the number of agencies that at present compete to supply the farmer with credit beyond what is good for him. There is, as was indicated earlier in this article, room for new financial institutions dealing in long-term mortgage loans. The market for such loans is curiously unorganized. Strictly speaking, neither the banks nor the agency companies are designed to lend upon such non-liquid securities as land. The first requisite of a banker is that he shall be "able to distinguish between a bill of exchange and a mortgage." The agency companies, while they do lend upon landed security, are neither able nor willing to find the whole of the fixed capital needed in the farming industry.

The farmer who desires an advance upon the security of his land must at the present time hawk his security about in an unorganized market. Some Government Departments have funds available for investment, large financial concerns such as insurance companies meet some of the demand, the legal profession is largely given over to money-lending of this type, which works in profitably with conveyancing and other legal work, and there is a fair amount of private investment. In such an unauthorized, rudimentary market the accommodation which the farmer receives and the terms upon which he receives it are largely a matter of chance. The lending-rates are much higher than they should be in a properly organized market where competition is mobilized and keen. The term of the loan also is usually too short. The legal and other expenses of periodically renewing mortgages for comparatively short terms add approximately 1 per cent. to the interest rates. This burden on the farming community is paralleled only by the worry and anxiety which such a chaotic state of affairs involves. The farmers, who only too often have been given more credit than they can economically handle, are crippled by the load of interest-payments. There is no means by which they can apply their savings or the fortunate receipts of a good year to the gradual reduction of their mortgage debt. They are, therefore, not encouraged to become permanent owners and tillers of the soil, but are inevitably driven to look for rising prices and increased land-values to lift them above their difficulties. They become speculators rather than farmers.

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* For the present agitation see MORMAN, *Farm Credits in U.S.A.*

It has proved possible in many countries, and it should be possible in New Zealand, to develop mortgage banks granting long-term loans and accepting both interest and repayment of capital upon a scale of amortization. This is practically what the State Advances to Settlers Department now does, but does in a restricted fashion. There seems no reason why a co-operative institution owned and controlled by the farmers themselves should not extend the principle and do even better work. But no such institution can get over the difficulties of the present mortgage situation, and it should not try to do so, by inflationary methods. If such a bank, once created, was given wide powers of deposit banking, note-issue, &c., it would experience very strong pressure towards inflation from those farmers and those districts which were in the worst financial difficulties following land speculation.

It is true that the banking operations of the Dominion are at the present time a close monopoly. It is also true that the margin between buying and selling rates of exchange, and similar profit margins, are so wide that the banking monopoly makes more than the commercial competitive rate of profit. The premium at which the shares of the various banks are held and the very strong financial position of the institutions are proof enough of this. There is a constant incentive, therefore, to interloping competition; but such competition could come successfully only from a financial institution strong enough to meet bitter opposition. The Bank of New Zealand is potentially not perhaps a State bank, but a bank under State control. The Government has the right to appoint the Chairman and a majority of the directors. The Government in fact, through its nominees, is in control of the bank's policy. It could, if it so desired, direct that policy so as to break through the monopoly which at present exists. To do so would be a far safer line of action than to create a set of new institutions undertaking liabilities on demand and investing the proceeds in such unsaleable security as land proves to be in a crisis. The bill-of-exchange business is different from the mortgage business and must be kept distinct.

There is upon the statute-book of the Dominion a Rural Credit Associations Act, passed in 1922. This measure was passed in response to an agitation raised on behalf of the farming community, but it did not by any means satisfy the agitation. Under it, any association of not less than ten persons may be formed, and then proceed to work between the banks and the farmers, much in the manner of the loan and finance companies previously described. Provision is made for deposits being taken from members at rates of interest to be fixed, and the association may borrow additional noney to be loaned out again for most of the purposes for which capital is required on farms. Members of the association are to be jointly and severally liable for the whole of the liabilities of the association. Within its limits the Act might possibly have proved a useful addition to the credit machinery of the country, but the maximum loan any member may obtain is £500, and this in itself indicates how little likely the Act is to help the particular trouble in which farmers find themselves for the moment. Actually it has been a dead-letter. The principle of joint and several security also is a drastic limitation upon the extension of credit by means of the new associations, but it is a well-recognized feature of the co-operative credit institution in other countries, and also of the cash credit system in Scottish banks.*

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* WOLFF, *People's Banks*, p. 30.

Towards the close of the session of 1924 another Bill was introduced in response to a powerful agitation and a threatened political crisis; but once again the proposed measure, though wider in its scope than the previous Act, was not acceptable to the Farmers' Union. It met with such a critical reception in so many quarters that it was dropped.

In the meantime the higher wool and meat prices have removed the urgency from the minds of those who see in a rural bank the means of providing cheaper credit. The agitation has therefore dropped; but the necessity for better organization of the mortgage market is as great as ever. If in the future a fall in prices should again occur it is probable that the agitation will be revived and in the end meet with some measure of success. The example of other countries is a potent argument in its favour. It should be remembered, however, that the conditions of New Zealand farming are very different from those under which the co-operative rural banks of Europe have proved successful. Instead of a peasantry closely tied to the soil, living on small, intensely cultivated holdings, reluctant to sell and move on even if that were possible, and accustomed to discipline of all kinds, we have a migrant farming community, for the most part practising predatory methods of farming, ready to sell at a profit, with more than adequate credit offering upon their security, which is far greater than the tiny holding of a European peasant. It is very doubtful whether New Zealand farmers will submit themselves to the discipline involved in co-operative credit.

The obvious remedy for such difficulties as followed the slump is not more credit, but a readjustment of farm-values. Implements, stock, and farm buildings purchased or erected at high prices depreciated heavily. The value of farm-products also fell heavily, and the land-values were far too high. It is necessary to get a revaluation of these liabilities before any stability can be reached. Once the farmers' outstanding liabilities are reduced and production again organized on a satisfactory basis, it will be possible to evolve a satisfactory system of credit advances; but it must be remembered that credit is not a mysterious energy giving power from a source unknown—it consists merely in the control given over the property of other people, and must be paid for by annual charges, and ultimately by repayment of the capital sum.

BLACK SPOTS ON FROZEN MEATS.

By A. M. WRIGHT, F.I.C., Chief Chemist, New Zealand Refrigerating Company (Limited).

THE rejoinder of F. T. Brooks (1) to the present writer's paper (2) is read with interest. As, however, the matters questioned by Brooks cover but one point only, it is suggested that a more accurate title for Brooks's polemical discussion would be that adopted above.

Some months ago the subject-matter of the paper now published by Brooks was circulated in New Zealand as a confidential communication; thus the writer has been unable until now to refer to a document which took shelter under such a plea.

Brooks, under the general title of "Moulds on Frozen Meats," takes specific exception to the writer's conclusions covering the so-called black

spots which have from time to time appeared on New Zealand frozen mutton.

It is of interest to note that, while Report No. 6 (Food Investigation Board), by Brooks and Kidd (3), had been perused by the writer before submitting his original paper for publication, the Report No. 17, by Brooks and Hansford (4), had not at that time been received by the writer.

It is realized by the present writer that to indulge in a controversy at a range of twelve thousand miles, involving a lengthy delay in reply and rejoinder, is a somewhat futile procedure; but since Brooks, both in the confidential communication and in the paper now under review, has sought to suggest that his laboratory experiments invalidate the writer's results covering the development of black spots on frozen meats at a point of origin, and in a number of cold stores in New Zealand, some reply might reasonably be expected when the opportunity to do so was publicly presented in New Zealand.

It is not wholly without interest to note that in those factories and stores in New Zealand which have adopted the precautions indicated by a close study of the causal organisms and their mode of development no black spots have appeared in frozen mutton, lamb, or beef. On the other hand, the writer has evidence of the development of black spots on frozen mutton where the conditions have been favourable and the supervision lax, such development taking place on meats which have been held for less than six weeks in cold storage.

Brooks in his paper appears to have assumed that but one degree alone of blackness indicates a black spot on frozen meat, and this the blackest. Certainly, if a spot of Cimmerian darkness is meant to indicate the blackness of a black spot on frozen meat, the writer accepts in general the findings of Brooks and his associates as to the causal organism, for at present the writer knows no other mould which can simulate *Cladesporium herbarum* in its density of blackness when grown upon a suitable medium. The writer is, however, unwilling to agree that the blackest spots found on frozen meat are alone to be regarded as black spots, nor is such a definition accepted by those connected with the frozen-meat trade in New Zealand.

No opportunity has as yet arisen to repeat the experiments originally carried out by the writer, but a number of check results have amply confirmed the fact that *Mucor mucedo*, *Penicillium glaucum*, *Rhizopus nigricans* have been isolated from black spots in frozen meats, and have, under the conditions noted, developed black spots when inoculated upon meats and subsequently frozen. An opportunity is being taken later on to repeat the work in question, and the results will be communicated in due course; in the meantime, the fact that Brooks has obtained negative results in his attempt to repeat the writer's work cannot be seriously regarded as a basis upon which to establish a claim for the invalidation of positive findings.

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(2.) A. M. WRIGHT. *N.Z. Jour. Sci. & Tech.*, vol. 6, pp. 208–11, 1923.

(3.) F. T. BROOKS and M. N. KIDD. *Special Report No. 6, Food Investigations Board.* H.M. Stationery Office, 1921.

(4.) F. T. BROOKS and C. G. HANSFORD. *Special Report No. 17, Food Investigations Board.* H.M. Stationery Office, 1923.

THE GEOLOGICAL HISTORY OF ROSS DEPENDENCY.*

By H. T. FERRAR, M.A., F.G.S., Geologist to Captain Scott's First Antarctic Expedition.

GEOGRAPHICAL AND HISTORICAL.

ROSS DEPENDENCY is defined as all that territory and seas to the south of latitude 60° S. which lies between longitude 160° E. and 150° W. This sector of the South Polar regions includes—(*a*) a portion of the Antarctic Ocean largely encumbered with floating pack-ice; (*b*) a seaway, the Ross Sea, almost ice-free during the summer months; (*c*) a sheet of ice, the Ross Piedmont-glacier, nearly 100,000 square miles in extent; (*d*) the snow-encumbered Edward VII Land bounding it on the east; (*e*) a belt of mountainous country 1,300 miles long (partly within and partly without the western boundary of the Dependency); and (*f*) a number of snow-covered islands. (See sketch-map, *N.Z. Jour. Sci. & Tech.*, vol. 6, p. 206; 1923.)

The name "South Victoria Land," given to the northern portion of this mountainous land by Ross, its discoverer, is now applied to the whole belt together with its hinterland. The mountains rise steeply from the coast to heights of 13,000 ft. and more, and form the front or edge of a somewhat lower featureless inland plateau. This plateau forms part of a polar continent, the coasts of which have been sighted in several places near the Antarctic Circle, as indicated on the inset map on the page opposite. There are two deep indentations in the coast on opposite sides of the South Pole, occupied by the Weddell Sea and Ross Sea respectively. How far south the former extends is not known; the Ross Sea depression extends to about 84° south on the 180th meridian. The South Pole, at an altitude of 9,500 ft., is situated on the plateau which probably extends towards the Pacific Ocean so as to connect with the little-known Edward VII Land. There appears to be an ice-divide (altitude 10,570 ft.) some 300 miles inland from the coast of South Victoria Land, from which great outlet glaciers drain eastwards through the mountainous belt to the Ross Piedmont-glacier or into the Ross Sea. This paper will deal mainly with the geology of South Victoria Land.

The earliest geological notes having reference to any portion of the region now known as Ross Dependency are found in the journal of John Balleny (Enderby, 1),† who, in 1839, discovered a group of islands, the Balleny Islands, noted an active volcano on one of them, and collected specimens of scoria and basalt. The next expedition to this region was that of James Clark Ross, in H.M.S. "Erebus" and "Terror." In the year 1841 Ross worked his ships through the pack-ice into the open seaway which now bears his name, discovered a lofty range of mountains, and, landing on an island (Possession Island), collected some rock-specimens and described the land as being of volcanic origin (2). Coasting southwards, he discovered an active volcano (Mount Erebus), an ice-cliff which he called the "Ice

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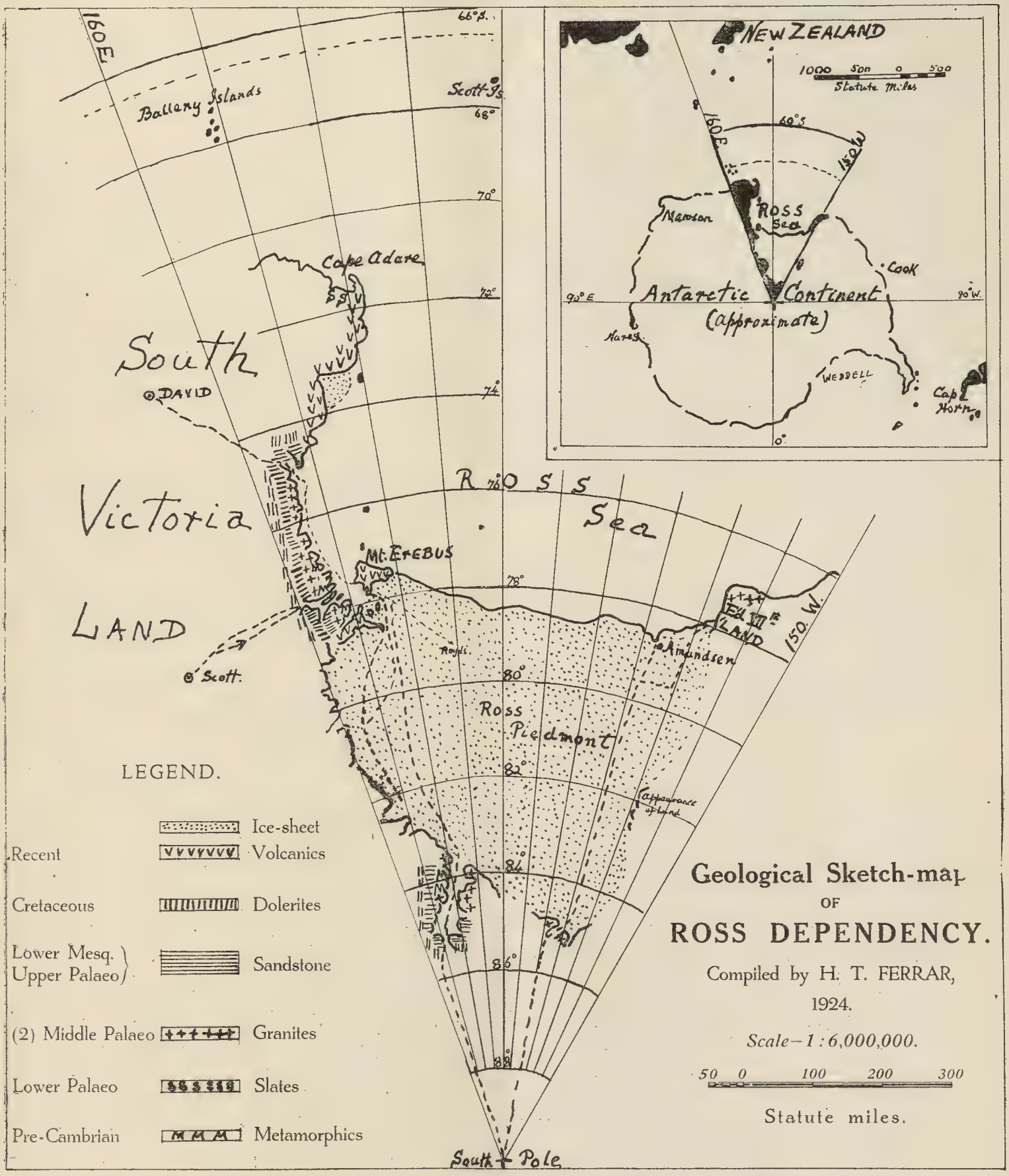
* Paper read at a meeting of the Geological Section of the Wellington Philosophical Society on the 13th August, 1924.

† Figures in parenthesis refer to the list of publications appended to this paper.

Barrier" because it presented a barrier to his further progress southwards, and noted appearance of land at the eastern end of the continuous ice-cliff. The rocks collected by Ross, which include basalts together with phonolites and granite boulders, were described in 1899 by G. T. Prior (3). Although the "Challenger" expedition of 1874-77 did not come very near the present area, the fact that sandstones, limestones, and shales (Murray, 4) were dredged up from a high southern latitude showed the possibility that rocks



other than of igneous origin occur in these regions. The rocks collected by C. E. Borchgrevinck from Cape Adare and from Possession Island in 1894 were described by T. W. E. David, W. F. Smeeth, and J. A. Schofield (5) in 1895, and by A. Geikie and J. J. H. Teall (6) in 1899. The "Southern Cross" expedition, which wintered at Cape Adare in 1899, brought back important additions to the rocks already known. These additions are siliceous slates and quartz-grits, which were described by G. T. Prior in 1902 (7).

The rock-specimens brought back from South Victoria Land by the National Antarctic Expedition of 1901–4 under Captain R. F. Scott are listed under about one thousand numbers, and are housed in the Mineral Department of the British Museum. There is a small representative collection in the Canterbury Museum, Christchurch. The collection in London includes much transported material, but most of the specimens were collected *in situ* by H. T. Ferrar, the geologist of the expedition, who prepared the monograph on their field occurrence (8). The petrological description was written by by G. T. Prior (9).

The next expedition to the region was that of Lieutenant E. H. Shackleton during the years 1907–9. He was accompanied by T. W. E. David, D. Mawson, and R. E. Priestley, who with other collaborators have prepared detailed geological reports (10).

The personnel of Scott's last expedition, 1910–13, included T. G. Taylor, R. E. Priestley, F. Debenham, and C. S. Wright, who have written physiographical reports on portions of South Victoria Land (11), and have assisted specialists in the preparation of the geological memoirs being published by the Trustees of the British Museum (12). The granitic rocks collected by Roald Amundsen's South Polar Expedition, 1910–12, from Edward VII Land and from the land near the South Pole, are described by J. Schetelig (13) and likened to the granites of South Victoria Land and to similar rocks collected by D. Mawson (14) from the region adjoining but to the north-west of Ross Dependency.

The geological results obtained by these various expeditions will now be summarized.

CLASSIFICATION TABLE.

The geological column, in so far as it is known, is shown in the following table :—

Recent—Low-level moraines, high-level moraines, basalts.

Pliocene (?)—Palagonite tuffs, limburgites, kenytes, phonolites, trachytes

(*Fifth hiatus, foundering and fracturing*).

Cretaceous—Quartz dolerites.

(*Fourth hiatus, erosion internal, slight folding.*)

Lower Mesozoic
Upper Palaeozoic } Beacon Sandstone formation.

(*Third hiatus, erosion internal, hypabyssal rocks.*)

Middle Palaeozoic (?)—Plutonic rocks, pink and grey granites.

(*Second hiatus, folding movements.*)

Lower Palaeozoic—The slate-greywacke formation.

(*First hiatus, erosion internal.*)

Pre-Cambrian—Metamorphic rocks, crystalline limestones, schists, &c.

BRIEF DESCRIPTION OF THE ROCKS.

1. *The Metamorphic Series.*—Crystalline limestones and schists representing metamorphosed calcareous and argillaceous sediments cover considerable areas in South Victoria Land and form the basement rocks of the region. Erratics of para-granulite representing metamorphosed sandstones occur in places. Associated with these rocks are gneisses derived from granites which intruded them, probably subsequently to their metamorphism. These altered sediments seem to have a wide distribution in Antarctica, for fragments of schist and gneiss were dredged up by the

"Challenger" near Mawson's western base in longitude 90° E., and by the "Discovery" near the Balleny Islands (longitude 155° E.) and near the coast of Edward VII Land (longitude 159° W.). They have been found *in situ* in Ross Dependency at Terra Nova Bay (latitude 75° S.); at points along the coast from McKay Glacier (latitude 77° S.) to Koettlitz Glacier (latitude 78° 31′ S.); and away south in latitude 84° 20′ S., on the west (left) bank of Beardmore Glacier. These rocks thus form a piedmont zone along the coast. They are regarded as of pre-Cambrian age, because they are so like the pre-Cambrian rocks of Brittany and of other parts of the world, and especially of South Australia.

2. *The Slate-greywacke Formation.*—The hiatus between the underlying metamorphic rocks and the slate-greywacke formation was probably a period of uplift and erosion followed by slight depression and deposition. The sands and clays which were then deposited have subsequently been altered to greywackes and well-cleaved slates, which make up the so-called slate-greywacke formation. The commonest clastic mineral of these rocks is quartz derived from two distinct sources—namely, from quartz veins and from quartzites. Since they contain no heavy minerals, they are thought to be derived from an older sedimentary series, probably the metamorphic series described above. Rastall, who examined these rocks, finds that the individual grains are markedly angular, and suggests that they were deposited by moderate winds during a glacial period. According to this explanation they should resemble loess deposits.

The slate-greywacke formation crops out continuously for a distance of thirty miles at least along the coast near the north end of South Victoria Land, from the head of Robertson Bay north-westwards to the farthest point reached by sledge parties. The rocks are folded over north-east to south-west axes. Priestley states that the folding becomes more intense towards the east, as if the pressure was directed from the east towards a resisting land-mass. A Lower Palaeozoic age is assigned to these sediments, which were folded before being intruded by the granites next to be described.

3. *The Plutonic Rocks.*—The plutonic rocks consist mainly of grey and pink granites, of which the latter is the younger. They, however, occur in close association, and both show gneissose selvages. Like the metamorphic series, they have a wide distribution. Erratics of granite have been found at almost every point visited between latitudes 71° and 84° S. Granites *in situ* have been seen in Terra Nova Bay, 74° 55′ S.; on Mount Gerlache and Mount Crummer, 75° S.; in Granite Harbour, 77° S.; on the banks of Ferrar Glacier, 78° S.; on the banks of Beardmore Glacier, 84° S.; and at Scott's Nunataks, Edward VII Land.

The granites exposed in South Victoria Land seem to be part of the surface of an enormous bathylith. This surface is near sea-level in Terra Nova Bay, and is thought to rise to a height of 1,000 ft. under Mount Gerlache; at Granite Harbour the surface is about 1,000 ft. above sea-level, whence it rises under Mount Marston and Mount England and attains a height of 5,000 ft. in the Royal Society Range (see fig. 1). Granite was viewed on the banks of Beardmore Glacier from near sea-level to a height of about 3,000 ft. The age of these plutonic rocks is about Middle Palaeozoic, being younger than the slate-greywacke series and older than the succeeding sandstone formation.

During the period, partly or wholly erosional, which followed the intrusion of the granites it would seem that dyke rocks were injected into

the metamorphic and plutonic series. Dykes of camptonite, kersantite, and banakite are found in the crystalline limestones of the Northern Foothills* of the Royal Society Range, and diorites, porphyries, and lamprophyres commonly occur as dykes in the granites. The period of injection of these dyke rocks is not known, but they certainly do not intrude the overlying Beacon Sandstone formation.

4. *The Beacon Sandstone Formation.*—As already indicated, sandstone-fragments were known to be widely distributed in the Victoria Land quadrant of the South Polar regions, but it was not until 1902, when the tabular Mount Nansen was seen from the deck of the "Discovery," that the probable source of these fragments became apparent. Since this date sandstone *in situ* has been examined by many members of Scott's and Shackleton's expeditions.

[*R. W. Skelton, photo.*

FIG. 1.—A sill of quartz dolerite resting upon the surface of the granite bathylith.

This sandstone, called the Beacon Sandstone formation, consists mainly of granitic quartz cemented with iron-stained silica, but sometimes it contains pebbles of quartzite derived from an older sandstone formation. In some places it is calcareous, and in other places it is arkositic or is ripple-marked and contains fossilized vegetal matter. It is estimated to be nearly 5,000 ft. thick, and the beds which build up this great thickness are conformable and nearly horizontal. It has been proved to occur in considerable thickness at places more than six hundred miles apart, and hence must extend still farther afield. Since it covers an area at least fifty miles broad from east to west in the Ferrar Glacier region, and underlies Mount Erebus and perhaps a great part of Ross Sea, it must once have covered a very great area.

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* N.B.—Not to be confused with the Northern Foothills of Terra Nova Bay.

The beds of the Beacon Sandstone are faulted but not folded; hence they have been subjected to radial stresses rather than to tangential compressions.

The fish-scales discovered near its base by F. Debenham are stated by A. Smith Woodward to be of Devonian age. The plant-remains discovered by R. E. Priestley, which probably belong to the upper portions of the formation, have been identified by A. C. Seward as *Glossopteris indica* Schimp. and allied genera of Permo-Carboniferous age. The bearing of this discovery and identification on such subjects as the poleward extension of Gondwanaland, or the distribution of Mesozoic floras or climatic changes in times past, is obvious.

5. *The Quartz Dolerites.*—Another hiatus, probably a period of erosion and slight folding, closes with the intrusion of great sills of quartz dolerite.

[*R. W. Skelton, photo.*

FIG. 2.—Beacon Sandstone intruded by quartz dolerite, south side of Ferrar Glacier.

This rock, when in the molten state, found its way through or past the boundary of the grey granite, and now occurs in the planes of separation between the grey and the pink granite, between the pink granite and the Beacon Sandstone, and between the beds of the sandstone, which it also cuts across (see fig. 2). It is estimated to be about 4,000 ft. thick, and has the same wonderful distribution as the Beacon Sandstone.

Normally it is an enstatite-quartz dolerite, but in places it is an olivine-bearing quartz dolerite. According to Prior (*Ann. Natal Museum*), these Antarctic dolerites are similar to the probably Cretaceous dolerites of Natal, and Benson (10*b*, p. 159) finds the resemblance to the Tasmanian dolerites so close that he suggests a similar Cretaceous age for the dolerites of South Victoria Land.

6. *The Volcanic Rocks.*—A period of erosion followed by fracturing and foundering was closed by the advent of a volcanic period which carries

the geological history of the region to the present day. The volcanic period opened with the eruption of trachytes and phonolites, and these lavas were followed by kenytes, limburgites, palagonite tuffs, and olivine basalts, which are often scoriaceous. These rocks all belong to one petrographical province, and apparently the sequence of eruption has been from rocks of medium basicity to basic. These volcanic rocks form most of the islands in the Ross Sea, and on the mainland extend from Cape Adare to Cape Washington and cover a large area in the neighbourhood of Mount Discovery. They are of Pliocene to Recent age.

7. *High-level and Low-level Moraines.*—High-level moraines, indicating a recent retreat of the ice, were first recorded as occurring in the South Polar regions by H. Arktowski in 1900. Since this date records of such recession have been numerous. In Ross Dependency moraines stranded more than 1,000 ft. above the present low-level moraines have been seen in many places on the slopes of Mount Erebus and on the mainland opposite. Bare *roches moutonnées*, valleys free from ice, or valleys containing ice-slabs or remnants of the glaciers which formerly filled them, and such features as piedmont glaciers with no visible source of supply, all bear evidence of a general progressive retreat of the ice.

At present most of the snow falling in the Antarctic regions falls into the sea, and the greater part of the atmosphere which circulates to the south of the isotherm of 0° C. is comparatively dry. The cold desert conditions mentioned by Ferrar (15, p. 382) go far to explain the cause of the diminution of the ice. One way of obtaining an increased precipitation of snow and consequent thickening of the ice-covering of South Victoria Land would be to cause the isotherm of 0° C. to move five or ten degrees farther southward either during successive summers or for a continuous period of longer duration. This would entail either an increase in the eccentricity of the earth's orbit, or a shifting of the earth's axis of rotation, or a migration northwards of South Victoria Land, or an increase in the mean temperature of the Southern Hemisphere. The last of these hypotheses seems the simplest. The recent desiccation of Ross Dependency should be reflected in some way by the Recent deposits of New Zealand.

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UPPER PALAEOZOIC (PERMIAN) FOSSILS AT CLINTON.

By J. MARWICK, D.Sc.

IN December, 1924, Mr. M. Ongley, while engaged in a geological survey of the Kaitangata Subdivision, collected near Clinton some interesting fossils. The collection contains species belonging to widely separated groups of the animal kingdom—namely, several corals, echinoderm fragments,

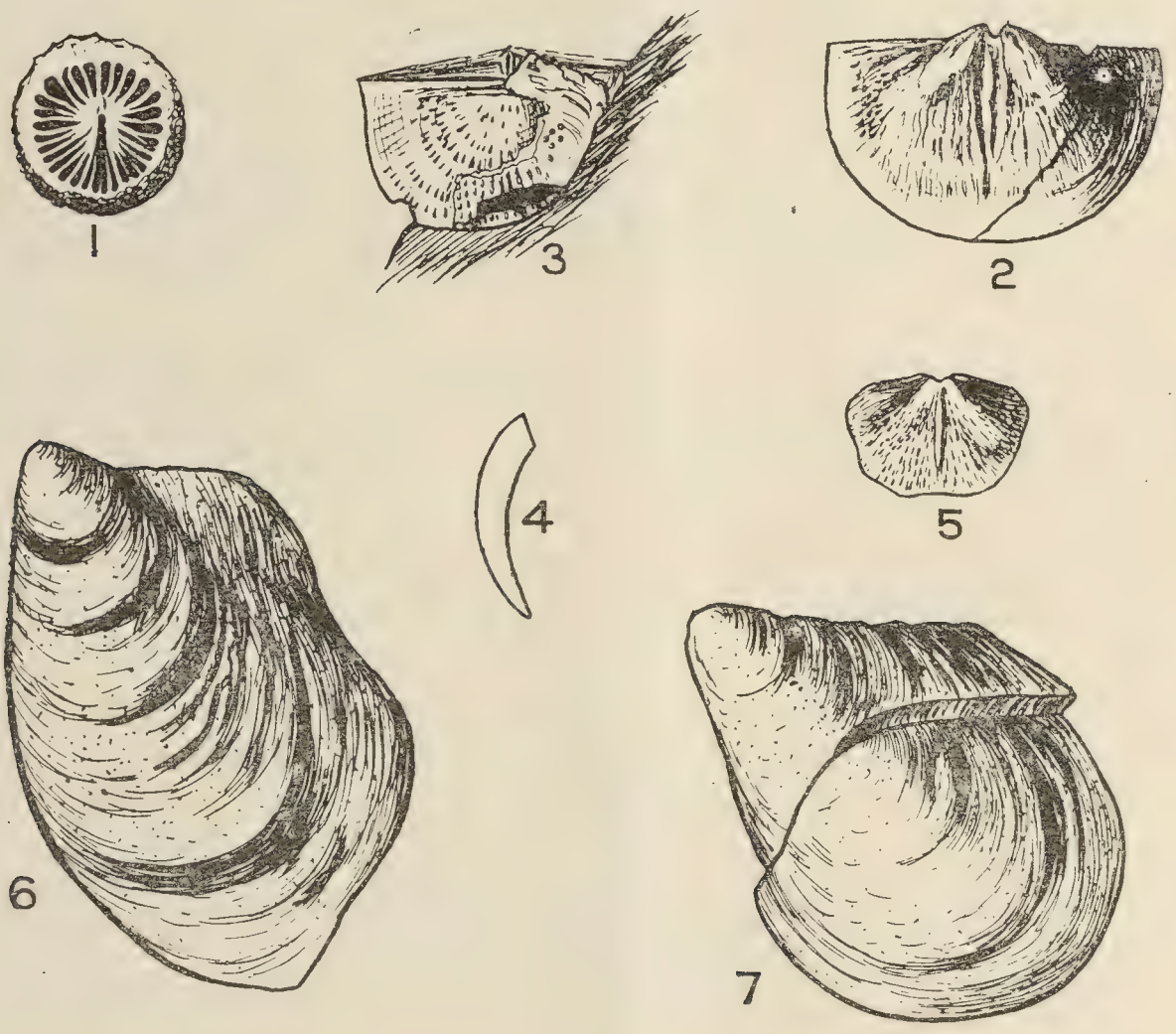

FIG. 1.—*Zaphrentis* sp.

FIG. 2.—*Chonetes* sp. cf. *vishnu* Salter: internal cast of ventral valve.

FIG. 3.—Ventral view, showing at the bottom a few scraps of the ventral valve; the black represents the mud filling the interior, and about half of the interior of the dorsal valve is to be seen. The impression of the ligamental area and delthyrium of the ventral valve appear above, while the left half of the figure represents an external cast of the dorsal valve.

FIG. 4.—Cross-section of complete shell.

FIG. 5.—Internal cast of dorsal valve.

FIGS. 6, 7.—Internal casts of new (?) genus of pelecypod.

(All figures natural size.)

brachiopods, two pelecypods, and a gasteropod. Of these, only a coral, a brachiopod, and a pelecypod are at all well preserved. They are as follows:—

Zaphrentis sp. (fig. 1).—The fossula reaches slightly beyond the centre, and of the thirty septa the one in the fossula is very short.

Chonetes sp. cf. *vishnu* Salter (figs. 2, 3, 4, 5).—As this brachiopod is represented by a large number of individuals, a fair idea of its characters

can be obtained. In shape it is transversely suboblong, with a straight hinge-line extending the full width of the shell. The dorsal valve is strongly concave, and the ventral valve strongly convex with a well-marked delthyrium. In outline this *Chonetes* is somewhat between *C. vishnu* Salter and *C. lissarensis* Diener from the Permian "*Productus* shales" of the Himalayas, but it is larger than either of these species. Concerning the age indicated, Diener said (1897, p. 18), "The true *C. vishnu* has not been found outside the Himalayan district of Painkhanda, but its nearest allies are among the leading fossils of Upper Carboniferous, Permo-Carboniferous, and Permian strata."

Pelecypod (? new genus) (figs. 6, 7).—Only internal casts have been preserved. The valves are equal and of mytiliform shape, with a long, straight hinge-line forming a decided posterior wing, and the shell-structure is coarsely prismatic. The specimens are therefore very like *Inoceramus*, but the concentric folds are weak and irregular, and the hinge area has not been seen. The shell from the Maitai series of Nelson described by Trechmann as *Aphanaia* sp. cf. *mitchelli* (McCoy) is probably closely related and may be identical; but the material at hand is insufficient to settle the question. As indicated by Dun (Benson, 1921, p. 18, footnote), this shell is not an *Aphanaia*, which is inequivalve and has no large posterior wing. A new generic name seems to be required for the Maitai shell; whether the Clinton fossils are really congeneric can be proved only by collecting a hinge showing similar longitudinal ligamental grooves.

The oldest fossils hitherto known from this district are those described by Trechmann from the Kaihiku Gorge and determined by him as of Ladinic (*i.e.*, Middle Triassic) age. The Clinton faunula possesses nothing in common with the Triassic faunas of New Zealand. The presence of the *Zaphrentis* and the *Chonetes* undoubtedly points to an Upper Palaeozoic age, probably Permian; and the pelecypod suggests that the containing strata are in the Maitai series as defined by Trechmann.

The enclosing rocks (fine conglomerate, tufaceous (?) sandstone, greywacke, and argillite) are described in the appended note by Mr. Ongley. Though indurated, they are not metamorphosed, and most of the fossils (all of the *Chonetes*) preserve their original shape. Many of the *Chonetes* retain their calcareous tests, most of them being ventral valves.

In *Geological Survey Bulletin 19* (p. 35) Marshall classed the Otago schists in the Mesozoic, as no fossils had been found between these schists and the Triassic rocks of the Nuggets and Kaihiku Gorge districts. Although no angular unconformity has been observed, and contemporaneous or subsequent metamorphism at depth may be advocated, the presence of a Permian or older fauna at a considerably higher horizon indicates that the schists should be considered as at least pre-Permian.

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DESCRIPTION OF THE LOCALITY.

By M. ONGLEY, M.Sc.

Clinton is on the railway, twenty-one miles west from Balclutha and twenty-six miles east from Gore, 400 ft. above sea-level, in the mile-wide valley of Kuriwao Creek, between the front ridge (800 ft.) of the Kaihiku Mountains on the south and the isolated Popotunoa Hill (744 ft.) on the north. The Kaihiku Mountains are a series of hogbacks trending 130° to 140° near the Kuriwao, with steep escarpments on the north-east and steep dip-slopes on the south-west. The beds dip 80° to 85° at the north-east, and more gently farther south, and two and a half miles from Clinton contain the Kaihiku fauna (Ladino-Carnic, Middle Trias).

Thirty chains north of the engine-sheds at Clinton a ridge 600 ft. high has in it coarse conglomerate 150 ft. to 200 ft. thick, striking 120° and dipping south 85°. The stones in the conglomerate are up to 3 ft. through, are well-rounded, and consist of greywacke and igneous rocks, including diorite, basalt, granite, porphyrites, &c. Below the conglomerate is a soft bed of blue-grey mudstone which does not give good outcrops. No contact was seen. Dense greywacke and more conglomerates of greywacke and igneous stones without visible bedding occur farther north, and some fifteen miles away is the Otago schist. The thick conglomerate can be followed for a mile, trending 120°. Its most westerly outcrop is in a ploughed field, and can be recognized by the igneous stones showing in the ploughed soil. Less than a chain south of the loose igneous stones, and dipping 80° south, is a small outcrop of dense dark argillite containing many small pieces of a fibrous shell; and 20 ft. above this on the hilltop are scattered pieces of greywacke, tufaceous (?) sandstone, &c., from which fossils were collected. These rocks extend half a mile farther west along the strike to the greywacke quarry south of Steel's house. The stone in this quarry, too, is fossiliferous, containing some complete specimens of the fibrous shell and many fragments of it.

The valley between the fossiliferous ridge and the Kaihiku Range is a mile wide, flat, and swampy, and has few, poor outcrops. The structure is obscure. In several places unbedded conglomerates of coarse igneous and greywacke stones crop out; and one outcrop of greywacke dips 80° north. The front ridge of the Kaihiku Range near Trig. W (873 ft.) is thick coarse conglomerate of 1 ft. boulders of greywacke and igneous stones; but this does not persist to the mouth of Kuriwao Gorge, where all the beds are greywacke and argillite dipping south at 80° to 85°. They dip south through the gorge for a mile and a half to the Kaihiku beds.

AUSTRALIAN LEPIDOPTERA IN NEW ZEALAND.

OCCURRENCE IN NELSON DURING 1924–25.

By ALFRED PHILPOTT, Assistant Entomologist, Cawthron Institute, Nelson.

As would naturally be expected, the lepidopterous fauna of New Zealand exhibits a fairly strong relationship with that of Australia. This relationship is mainly confined, however, to those groups which were established

in Australia before its severance from New Zealand, so that a large number of groups which have entered, or have been developed in, Australia since that time are unrepresented in New Zealand. The long geological isolation of the islands has also been responsible for a noteworthy general divergence between the parent stock and the later New Zealand descendants. Owing to this it is frequently an easy matter to pick out the Australian and New Zealand representatives of groups which are common to both countries. For instance, the species of such genera as *Crambus*, *Borkhausenia*, *Hydriomena*, and *Xanthorhoe* can usually be assigned with confidence to one or other distributional area, the difference of facies being most marked, though not perhaps permitting of exact description.

But in addition to this original relationship of the Lepidoptera of the two countries there is a slight element in the New Zealand fauna which has been derived from casual immigrants since its separation from the mother continent. A few of these waifs and strays doubtless reached New Zealand prior to European occupation, but as soon as Australian shipping began to call here the chances of successful introduction were very greatly increased.

During the past spring and summer the weather in Nelson has been very broken, there having been an unusual number of days on which rain fell and a corresponding variation in temperatures. But, despite these apparently unfavourable conditions, there has been quite an exceptional number of occasional visitants in the Lepidoptera. These will now be referred to in detail.

NYMPHALIDAE.

Hypolimnas bolina L.—On the 21st January, 1925, a fine female of this handsome butterfly was captured at Stoke by Mr. J. Kraig, who kindly presented it to the Cawthron Institute. Another specimen, a very battered female, was sent to the Institute a few days later, and Mr. T. Gordon, of the Institute staff, caught a third of the same sex in the Cawthron grounds. In addition to these, some eight or ten others, comprising both sexes, were seen about the town or in the surrounding district.

H. bolina is common in the eastern portion of Australia, ranging from Cape York and the adjacent islands to Sydney. The larvae feed on various species of Portulaceae, both wild and cultivated. As plants of this family have been introduced into New Zealand, there should be no lack of food for the butterfly's larvae if breeding actually takes place here.

Precis villida Fabr.—Two specimens of this species have been taken in the town itself by Mr. E. S. Gourlay. The first was captured on the 27th February, and the second on the 5th March. Waterhouse and Lyell (*Butterflies of Australia*) refer to this species as "one of our most abundant and widely distributed butterflies." It has been recorded in New Zealand at intervals since 1886. Various species of plantains are the usual food plants of the larva, but it has also been found on snapdragon (*Antirrhinum*) and the Australian centaury (*Antheraea*).

The specimens taken by Mr. Gourlay were in quite good condition, as also were some examples of the preceding species. It seems almost incredible that wind-borne specimens should arrive here without being considerably abraded, yet if the species really breeds here it is extraordinary that the larvae have not been frequently noticed. The most probable explanation seems to be that the species is in some way introduced by shipping while in the pupal stage.

NOCTUIDAE.

Ophiusa janata L. (*melicerte* Drury).—A common Australian species. Four examples have been taken at the Cawthron Institute this season, the first being secured on the 24th February and the last on the 5th March. Three of these were found in the Institute building by members of the staff, and the fourth was taken in the evening in the grounds. All but one were in a more or less worn condition. *O. janata* has been recorded in New Zealand on several previous occasions.

TORTRICIDAE.

Capua intractana Walk.—This species, first observed in 1923, is now quite common, and during the autumn months numbers come to any lighted window. It is common in the eastern and southern parts of Australia.

Tortrix postvittana Walk.—A very common Australian moth. It was first observed in New Zealand at Wellington, in 1891, by Mr. G. V. Hudson. It is now abundant at Nelson, and its caterpillar is one of the worst of the orchard pests known as "leaf-rollers."

EUCOSMIDAE.

Spilonota macropetana Meyr.—This well-known Australian species seems to have been first reported in New Zealand in 1921, when a specimen was submitted to Mr. Hudson by the Department of Agriculture and subsequently identified by Mr. Meyrick. In March, 1923, it was noticed at Havelock North, and later in the same year was found at Nelson. It is now fairly common here, and it is quite possible that, as its numbers increase, it may develop into one more serious pest of the blue-gum (*Eucalyptus globulus*).

Crocidosema plebejana Zell.—Another common Australian Eucosmid. It was first observed in Nelson in the summer of 1920–21, and is now abundant. The food plants of the larva are *Althaea* and *Lavatera*.

TINEIDAE.

Lindera tessellatella Blanch.—A fairly-well-known Australian Tineid. It was first recorded in New Zealand from several specimens taken in Nelson in 1922, but an unlabelled example in the Norris collection of the Dominion Museum must have been secured long prior to that date. Since 1922 the species has much increased in numbers, and it is now not uncommon.

CONVOLVULUS HAWK-MOTH.

Though not coming under the title of this article, it may not be out of place to record here the remarkable sudden appearance in Nelson this season of great numbers of the convolvulus hawk-moth (*Sphinx convolvuli* L.). From about the 20th February to the middle of March this handsome species, which is usually of quite rare occurrence in this district, occurred in great numbers. In all parts of the town they might be found at dusk hovering over such flowers as petunias and convolvuli, and specimens from many parts of the province were forwarded for identification. From Mr. F. G. Gibbs I learn that a similar influx of this moth occurred about twelve years ago, and another, though less abundant, immigration some six years previous to that. The normal distribution in New Zealand appears to be north of Napier, where it is common enough, particularly in those localities where the kumara (*Ipomoea*) is grown. It should be mentioned that besides the mature insects several well-grown larvae were found; the species must therefore pass the winter either in the larval or pupal stage.

OCCURRENCE IN THE NORTH ISLAND.

By AMY CASTLE, F.E.S.

Early in February last Mr. A. Ferguson captured a single specimen of the rare butterfly *Precis villida* at Tutukaka, and I understand that no further specimens were seen. The record of this butterfly in the North Island dates from 1886, at Wellington. In 1893 Mr. R. Holloway observed it at New Plymouth. The Dominion Museum has a single specimen, labelled "Papaitonga, 1896," and probably captured by the late Mr. Percy Buller. The appearance of a single specimen after nearly thirty years does not encourage the belief that *Precis villida* is established in the North Island, but rather that it is a stray immigrant from Australia.

While collecting at Whangarei in February last, Colonel R. W. Tate found a worn specimen of *Ophiusa melicerte*. Subsequent searches were made, without success in finding any other specimens. This rare moth has not been recorded in the North Island since 1904—twenty-one years ago—when Mr. Creagh O'Connor captured ten specimens at Titahi Bay, a locality apparently favourable, as many were seen at the time. Wellington, in 1876, is the first record of the appearance of *O. melicerte*.

A specimen of the rare sphingid *Deilephila celerio* was presented to the Dominion Museum by Mr. E. M. Toogood, who captured it in the Wairarapa district in March, 1925. He states that it flew and rested in company with its allied species *Sphinx convolvuli*. *D. celerio* was plentiful in 1904 at Titahi Bay, and had not, as far as I am aware, occurred elsewhere in the North Island.

Another sphingid, *Sphinx convolvuli*, has been very plentiful since late January, and specimens continue to arrive, though often in a very worn condition. The larvae and pupae have also been forwarded to the Museum, and show that this moth is established in New Zealand. Up to the present record single specimens only have occurred; this year, eighteen specimens have been captured, often in groups of two or three, from localities ranging from Whangarei to Wellington.

The latest, and hitherto an unknown species in New Zealand, *Dasypodia cymatoides*, taken at Whangamarino and Whangarei, is perhaps the most interesting of the Australian immigrants. At first sight these moths, six of which were secured, appeared to be melanic forms of *Dasypodia selenophora*, a closely related species, but on examination they proved specifically distinct. The characteristic difference is the much darker colour, smaller and less distinct eye-spots, more numerous wavy transverse basal markings on the forewings, and the continuous transverse wavy subterminal line from costa to dorsum of both forewings and hindwings. The specimens are apparently recent emergences, though several are badly damaged—probably the result of handling—and it is evident are not recent arrivals in the imago form. Acacia-trees, the reputed food plant of *D. selenophora* in its larval state, are plentiful at Whangamarino. Investigation may prove that *D. cymatoides* subsists on acacia.

OCCURRENCE IN NELSON AND TARANAKI.

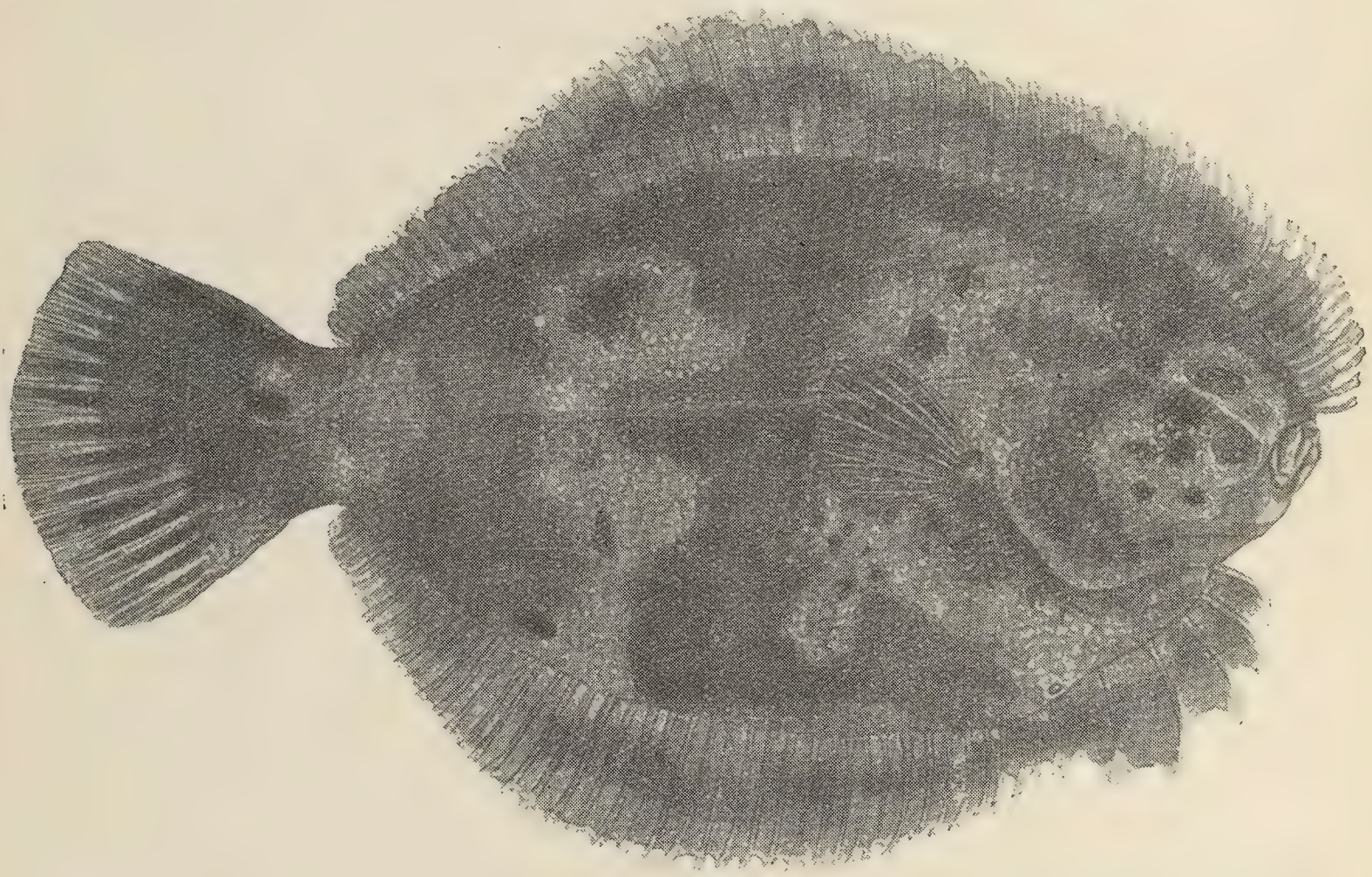
By JOHANNES C. ANDERSEN, F.N.Z.Inst.

I should like to record the capture by a schoolboy of a *Hypolimnas bolina* at Ihamatua, thirty-one miles north of Greymouth, on the 12th June, 1924. It was a male, $3\frac{3}{4}$ in. in wing-expansion, and was taken in grass one cold wet evening. Another schoolboy, in the previous year (December, 1923), captured a female *Hypolimnas* at Motunui, fifteen miles north-east of New Plymouth: the wing-expansion was about the same, $3\frac{3}{4}$ in. I noted these occurrences in the *School Journal* for September, 1924.

THE BLACK OR RIVER FLOUNDER OF NEW ZEALAND (*RHOMBOSOLEA RETIARIA*).

By W. J. PHILLIPPS, F.L.S.

THE river-flounder is one of the common edible fishes of Wellington. Though not so common as either the yellow or sand flounder, it is much in demand as the chief delicacy among all species of flat fish eaten by the New Zealand public. From time to time I have examined thirty individual specimens which have arrived in our markets from Thames, Hastings, and Christchurch, and at first inclined to the opinion that the



[*F. E. Clarke, del.*

DIAMOND PLAICE.

North and South Island species were distinct. With most fishes a considerable discrepancy in the number of fin-rays in specimens from different localities may indicate a new species, but in this instance the great variability evidenced both in colour-marking and fin-rays may be indicative of locality varieties the characters of which are not always constant.

The figure given below is from the drawings of the late F. E. Clarke. It is labelled "Diamond Plaice, October 13th, 1870, Hokitika," and is an excellent representation of the species. The accompanying fin formula reads—D. 67; C. 17; A. 46; V. 5; P. 11; and B. 7.

A careful examination of this flounder was made in 1911 by Waite in *Rec. Cant. Mus.*, 1, No. 3, p. 207, where a description and figure are given. Waite found the fin formula to be—D. 60; C. 18; A. 43; V. 6; and P. 11 (right and left sides). It will be seen that all counts of fin-rays, except in the case of the pectoral, disagree with those enumerated above.

In a Dominion Museum stuffed specimen I count—D. 64; A. 43; V. 6; and P. 11 (right). The type described by Hutton (*Trans. N.Z. Inst.*, 1873, vol. 5, p. 268; 1874, vol. 6, p. 107) had the following radial formula: D. 65; A. 48; V. 5; P. 9 (right) and 10 (left).

Among examples which I have examined I found that all fin-ray counts were liable to vary. The anal was generally 43, the ventral generally 6, and the pectoral generally 10. A typical fin formula may be written as follows: D. 60–67; C. 12 or 13 true rays; A. 43–48; V. 5–6; P. 9–11.

Waite (*loc. cit.*) states that the species attains a length of 17½ in.; but the average appears to be 6 in. smaller, and examples are rarely seen over 15 in long.

The characteristic red spots are not always distinct, though red markings of some sort are always present. The colour of an average example as it arrives in the Wellington markets is as follows: Lips deep yellow; ventral and anal yellowish, with red towards the tips of rays; dorsal darker yellow; body mottled with olive-green, being darker towards the dorsal surface, the colour blotchy, particularly in neighbourhood of lateral line, which is distinctly red throughout its length.

Interesting external points of character are: Scales are larger on the lateral line, back, and ventral surface, interspersed with smaller scales which are abundant on the head and in neighbourhood of pectoral. Scales are not always imbricate in posterior portion of the body. Nostrils are on a smooth area in front of the eyes, and may not be as near the upper eye as indicated in Waite's figure (*loc. cit.*).

This flounder may be distinguished from all others in our waters, firstly, by its darker appearance, and, secondly, by its smaller eye, the diameter of which is contained 7 times in the length of the head. Waite (*loc. cit.*) states that the teeth are on the blind side only; small, and in several rows. To this may be added that in the lower jaw they come more round towards the right and are stronger than in the upper.

The black or river flounder was known to Maoris in most parts of New Zealand, and large numbers were speared in all large gently-flowing rivers. Apparently the species prefers a sandy river with plenty of shade, as it is rarely taken in large fast-flowing or rocky streams. Some Native tribes referred to the species as *patiki mohoao*. The term *patiki* was generally used to apply to the common sand-flounder (*Rhombosolea plebeia*), though the term is also a generic one and applies to flounders in general.

PHYSICULUS (LOTELLA) RHACINUS (FORSTER).

A Record of its Capture in Otago Waters; with some Notes on its Range and Vernacular Nomenclature.

By MAXWELL W. YOUNG, F.C.S., Biologist Portobello Marine Biological Station, Dunedin, N.Z.

A SPECIMEN of this rather rare fish was captured off Cape Saunders early in 1924, and kept in captivity for several months. Before its death my curiosity was aroused by one of the staff calling it a "rock-cod" and

stating that that was the name used in the north even where the "blue cod" (*Parapercis colias*) was also caught.

After its death I examined the fish carefully and came to the conclusion that it was a specimen of *Physiculus (Lotella) rhacinus* (Forster). The fish, which is about 1 ft. long, agrees with the imperfect descriptions and drawings of the species; but I wish to state that, although these exclude any of our known fishes, they are far from good. I think the whole of the lesser known Gadidae require to be redescribed and drawn afresh, as it will be seen from a careful perusal of the literature cited that they have been well mixed up from time to time. Another matter touching on the recurring annoyance of vernacular names is that up till 1891 *Lotella rhacinus* was universally accepted as the hake; then, in 1912, Waite, for no apparent reason, transfers this name to *Merluccius gayi*, although he admits that the records of these fish were hopelessly mixed on the expedition. To save the reader's time, and as some of the works quoted are not generally available, I have given a summary of the contents with each reference, instead of merely quoting each item as a footnote.

The recorded range of habitat is from Mokohinau Island in the north to the Auckland Islands in the south and the Chatham Islands in the east. The fish seem to favour the same rocky bottoms as the blue cod.

Three specimens are now available for reference in the Otago University Museum, as follows: (1) Spirit specimen from Mokohinau (Sandager); (2) stuffed specimen from the Auckland Islands; (3) spirit specimen from Otago (the subject of the present note).

LITERATURE, WITH A SUMMARY OF THE DATA IN EACH CASE.

1872. J. HECTOR. *Cat. N.Z. Fishes*, p. 116. *Lotella rhacinus* = hake, with a note on its relationship to *Physiculus bacchus*. He calls *Gadus australis* (Hutton) the "haddock."

1872. F. W. HUTTON. *Trans. N.Z. Inst.*, vol. 5, p. 266. Records *Lotella rhacinus* from the Chatham Islands.

1877. P. THOMSON. *Trans. N.Z. Inst.*, vol. 10, p. 326. *Gadus australis* = haddock.

1886. R. A. A. SHERRIN. *Handbook N.Z. Fishes*, p. 17. *Lotella rhacinus* = hake. *Pseudophycis brevissculus* = whiting. Reports *Lotella rhacinus* from the Chathams, after Hutton.

1887. F. S. SANDAGER. *Trans. N.Z. Inst.*, vol. 20, p. 131. *Pseudophycis* sp. Noted as common, with remarks on variation of size and fins. Specimens sent to Hector. The spirit specimen (1) in the Museum is probably one of these, as it is labelled with Sandager's name.

1891. G. M. THOMSON. *Trans. N.Z. Inst.*, vol. 24, p. 210. In report from Cape Maria van Diemen, where the terms "blue-fish" and "rock-cod" (*Parapercis*) are used together, I suspect that the former were specimens of *Physiculus rhacinus*, and this would extend the range a little.

1891. G. M. THOMSON. Same paper, p. 212. Hake = *Lotella rhacinus*.

1912. E. R. WAITE. *Rec. Cant. Mus.*, vol. 1, pt. 2, p. 182. This is where the confusion starts. He records *Merluccius gayi* (Guichenot)—syn. for *Merlus gayi* (Guich.) and *Gadus australis* (Hutton)—as the "hake," and makes no independent record for *Physiculus rhacinus*, but admits that the records of the two fishes were in a state of hopeless confusion, thus tacitly admitting that specimens of both were recorded under the same name.

1921. G. M. THOMSON. *Board Sci. and Art. Bull. No. 2*, p. 74. *Merluccius gayi* (Guich.) called "hake" or "whiting." No record of *Lotella rhacinus*. I think that Mr. Thomson should have adhered to his nomenclature of 1891 and left *Lotella rhacinus* as the hake and *Merluccius gayi* as the whiting or haddock.

In conclusion, whilst admitting that vernacular names are not necessary for scientific work, one must consider the layman, who does not appreciate the reasons for applying bewildering Latin names, and it should be a duty with scientists to reserve as far as possible the common name for the fish to which it is generally applied. In all cases this is not possible—as, for example, in the North and South Island kingfishes, and in the North and South Island butterfishes, which are totally different in each case; but *Lotella rhacinus* was early accepted from one end of New Zealand to the other as the hake, and I think that it would save a good deal of confusion if scientists were to leave it so and keep the term "whiting" or "haddock" for *Merluccius gayi*.

ZOOLOGICAL NOTES.

Occurrence of the Australian White Ibis in New Zealand, by Perrine Moncrieff, R.A.O.U.

The white ibis captured by Mr. Rogers at Appleby, near Nelson, appears to be an immature specimen of the Australian white ibis (black-necked), *Threskiornis molucca*.

Description.—Irides, forehead, and crown dark browny-black. Ear-coverts black. Chin black, throat white. Primaries white, pointed with black at tip. Secondaries similar. Tertiaries mottled dark brown, almost black. Very faint dust-coloured mottling on scapulars. Bill, legs, and feet black. The arched bill is very slightly larger at tip. A spot of black on the flank is seen when the wings are raised. Tail and other parts of the body pure-white. Feathers cover the head and neck. There are no bare places.

There appears to be no reason to suppose that this bird is one escaped from captivity. The only facts which led Mr. Rogers so to think were its advent about the same time as two strange ships into Nelson Harbour, from which it might possibly have flown, and the very faint dust-coloured markings on the scapulars, which he first took for dirt-marks—signs that it had lived in captivity.

The bird was apparently seen by several people prior to its capture, even as long as a week before Mr. Rogers secured it. This is worth noting, as about the 5th March Nelson was visited by a strong north-westerly gale, which strengthens the theory that the bird was blown over from Australia.

Mr. Rogers first saw the ibis feeding on the mud-flats, and at his approach it flew into a tree, from which it descended, merely to return thither to roost at sunset, choosing a perch some 30 ft. above the ground. In flight the use of its wings was very powerful.

Although young, the bird is very healthy, taking about twenty-six minnows per meal. Whilst under observation it frequently ejected

undigested bones and scales, not in a round, firm pellet, like an owl's, but in a small oval heap of matter like wet sand in appearance.

When caught for inspection it emitted a dull croak like the cry of the paradise duck—the first time it had made a sound since its capture.

The Eggs of the Katydid, *Caedicia simplex* (Walker), by A. M. Lysaght.

Caedicia simplex (Walker), popularly known as the katydid, or scissor-snip, is a green leaf-like insect which is very abundant in certain localities throughout the summer.

Eggs of *Caedicia simplex* on rose-bush (enlarged).

The laying-period extends from the beginning of March till the end of April. Several males and females were kept in captivity, and five of the females deposited eggs. One laid twenty-five on a twig of *Nothofagus Solandri*, and, later, six more on the green twig of a rose-bush. Three others laid six, four, and three eggs respectively on *N. Solandri*, while a fifth deposited four on the dark wooden framework and one on the white paper on the floor of the breeding-cage. Another female which was well supplied with twigs of *N. Solandri* refused to oviposit in captivity, though for more than a week before she died she carried an egg protruding from her oviduct.

The egg is oval, very slightly narrower at one end than the other, measures about 3·25 × 1·4 mm. The greatest width of the base is 0·75 to 0·8 mm. The two sides of the egg have a slight tendency towards being concave. They converge to form a blunt upper edge. The base is comparatively broad, and turns up at either end. It rests on the floor of the oviduct before it is deposited. The chitinous shell is black and very finely pitted. After deposition it has a mottled rough appearance, due to a gummy substance which is secreted by the female when fastening it to a twig. When seen under a lens this secretion has a papery lichen-like appearance. The eggs on which it is present exhibit a striking resemblance to the bark of *N. Solandri*. The majority of the eggs are laid in single rows, though in one instance they were deposited on both sides of a slender twig. The base of each egg is firmly fastened to the bark, and each overlaps that in front of it. There are usually from two to six eggs in each row, but solitary ones occasionally occur. Those which are laid late in the autumn do not hatch until the spring, but nymphs from eggs of an earlier date pass the winter as such.

Habitat of *Anoura spinosa* Lubbock, by W. W. Smith.

The February number of this *Journal* contains an excellent paper by Dr. R. J. Tillyard, biologist of the Cawthron Institute, Nelson, entitled "Primitive Wingless Insects." In dealing with the family Poduridae the author stated that "two small species have been described from ants' nests in New Zealand—viz., *Lipura incerta* Moniez, and *Drepanura brachycephala* Moniez." Referring to the subfamily Anourinae, Dr. Tillyard stated, "New Zealand and Tasmania share between them the distinction of possessing the giants of the whole order in the three fine species of *Anoura*, found hiding in moss or under stones and logs."

Some years ago I sent a small tube containing specimens of *Anoura spinosa* Lubbock, to Professor Moniez in Belgium, and three years ago I posted specimens to Professor Chilton, of Canterbury College. In the letters accompanying both tubes I stated that they were from ants' nests, and also enclosed specimens of the ants from the nests where I procured them. They occur in the nests of *Huberia striata* Smith, and *Monomorium nitidum* Smith, located under damp stones on the Canterbury Plains. In Taranaki I find them in the nests of *Strumigenys antarctica* Forel, located in or under damp, decaying logs. This ant forms very large communities in the prostrate logs, in which they also form long tunnels and chambers, which are cool and well adapted to the habits of these delicate and minute wingless insects. They also occur in accumulations of damp leaves and humus on the floor of the native bush apart from ants' nests.

ENTOMOLOGICAL WORKS.

(1.) **An Introduction to Entomology,** by Professor J. H. Comstock, Cornell University, Ithaca, N.Y. Comstock Publishing Company. Pp. xix + 1,044, with 1,228 text-figures. (No price given.)

(2.) **Insects, their Structure and Life: a Primer of Entomology,** by Dr. G. H. Carpenter, Keeper of the Manchester Museum. Second edition, revised. J. M. Dent and Sons, London and Toronto. Pp. viii + 335, with 4 coloured plates and 184 text-figures. Price 10s. 6d. net.

Recent years have seen the appearance of a number of entomological text-books, both general and economic, of very varying merits. The two volumes before us can be unhesitatingly recommended to entomological students as two of the very best yet published. Though the price of Professor Comstock's monumental work is probably high, the volume contains such an immense amount of valuable information that no student of entomology can afford to be without it; for beginners, and those whose purse will only extend to a less expensive book, Dr. Carpenter's second edition offers a less extensive but very valuable presentation of the main facts about insects and their habits.

(1.) Professor Comstock is well known as the chief originator of the Comstock-Needham system of venational notation, which has done more than any other step to consolidate the study of insects of various orders.

For many years the most successful teacher of entomology in the United States, he now, at an advanced age, gives to the world this monumental work, which embodies the main outlines of his teaching. The book is the memorial of his great life-work. Part I, occupying pages 1 to 205, and giving a general account of the external and internal morphology of insects and their metamorphosis, was published as a separate volume in 1920; the remainder of the book, which has occupied the author's last four years, now appears for the first time, and consists of a very detailed account of the separate orders of insects. The definitions of the orders are set out clearly, and usually with consummate skill and accuracy. We note, however, on page 227, an error regarding the structure of the legs in the Collembola: these consist of only four segments, the last of which is either the combined tibio-tarsus, or else the tibia with the tarsus entirely suppressed except for the claw portion. We are glad to find that the author has reconsidered his position with regard to the Micropterygidae (page 592). Not long ago he removed them to the Trichoptera, but now very wisely returns them to the Lepidoptera, where they obviously belong. We must also enter an emphatic protest against the separation of the Homoptera as a distinct order from the Heteroptera (Hemiptera of this volume); neither on palaeontological nor on morphological grounds can this separation be defended, and we should like to hear the hemipterists of all countries speak out clearly on this matter. A number of errors in the application of the venational notation in certain orders (notably in the limits of media, cubitus, and first analis) still persist, though the correct interpretation has been pointed out again and again by recent workers; and we venture to think, in particular, that hymenopterists will never accept the hopelessly involved McGillivray notation for the veins of that order, especially as it is completely disproved by recent fossil discoveries. Professor Comstock's work is of such a high standard, and carries such weight with entomological workers, that it is important that these points should be noticed; the greater the author's reputation, the more serious becomes each error which he countenances. Like most American text-books, the book is heavy for its size; this is inevitable with the paper used, which is prepared for half-tone as well as line illustrations. The figures are uniformly clear and well selected, covering the ground of the text very fully. There is a very large and well-selected bibliography, and the index is very complete. We congratulate the talented author on the completion of this fine work, which must from now onward definitely take the place hitherto occupied by Packard's older treatise.

(2.) Dr. Carpenter's book is a new and much improved second edition of a work published by him twenty-five years ago. It has undergone a thorough revision, and its value is much enhanced by the addition of four excellent coloured plates. Dr. Carpenter is, we think, at his best in the more general discussions about the life-history (chap. ii), the surroundings of insects (chap. v), and their pedigree (chap. vi). The accounts of the separate orders suffer somewhat by compression; we feel, for instance, that even elementary students of the present day should not be informed that the orders of earwigs, stone-flies, and may-flies contain but a single family apiece; for, as a matter of fact, the recognized families in these smaller orders stand further apart from one another, and are much more easily recognized, than most of the so-called families in the larger orders. The selection of the illustrations is somewhat uneven, both in quality and in their elucidation of the text: *e.g.*, in the Diptera all the illustrations are allotted to the higher Calyptrate types, while we have to turn back to

page 9 to find a figure of a Nematocerous type, and the extensive division of the Brachycera Orthorrhapha is left entirely unfigured. And we must protest against the inclusion of the may-fly in figure 111, on page 165, which, with its long slender antennae and impossible venation, would make poor Swammerdam turn in his grave. These, however, are only small blemishes; the book as a whole is well up to date, and the scheme of orders submitted is superior to that of Comstock, the only weak feature being the inclusion of the Embiaria and Zoraptera with the termites or Isoptera. The Neuroptera are correctly placed next to the Mecoptera (Comstock unaccountably removes them far from all other Endopterygota), but we should like to see the Strepsiptera kept next to the Coleoptera. The author is generous in his appreciation of the arguments of other workers opposed to his views—*e.g.*, on the question of the maxillulae or paragnaths—and has selected his very useful bibliography with evident care. When we consider the present cost of printing, and the prices at which other text-books, good, bad, or indifferent, have been put on the market, we can only marvel at the cheapness of this excellent work, and advise all young students of entomology to secure a copy for themselves. R. J. T.

Guide to the Study of Tsetse-flies, by Professor R. Newstead, F.R.S., with the collaboration of Alwen M. Evans, M.Sc., and W. H. Potts, B.A. 1924. 4to.; pp. xi + 268, with 28 plates and 4 maps. Published for the University Press of Liverpool (Limited) by Messrs. Hodder and Stoughton (Limited), London. Price £1 net.

If one were asked to name the outstanding services rendered to mankind by the science of medical entomology, one would name without hesitation the remarkable achievements of the discovery of the life-history of the malaria parasite, and its association with anopheline mosquitoes on the one hand, and, on the other, the discovery of the causative organism of sleeping-sickness, or trypanosomiasis, and its association with the flies of the genus *Glossina*, known generally as tsetse-flies. In both of these problems the Tropical School of Medicine of the University of Liverpool has played a leading part. The author of the present volume on tsetse-flies has been studying the problem for twenty years, and he now gives us the result of his labours, and those of many other workers (to which very full references are given in an extensive bibliography), rightly terming his work a "guide" rather than a "treatise" or "memoir," so as to indicate the still far from complete nature of the solution of the problem presented.

The causative organism of the disease known as "sleeping-sickness" in man and "nagana" in domestic animals, both of which are generally fatal, is a minute organism found in the blood, called a "trypanosome"; hence the diseases to which they give rise are known by the general term of "trypanosomiasis." The natural reservoirs of the parasite are (*a*) certain wild animals, chiefly species of antelopes, which harbour the parasite without suffering from it, and (*b*) the tsetse-flies, which are the definitive invertebrate hosts of the parasite, and spread the disease by biting. The usual method is that the fly takes in the parasite through biting a diseased animal or person, and then a period of from eleven to eighteen or more days elapses, during which the life-cycle of the trypanosome progresses a stage further, finally rendering the fly highly infective, so that the disease is given to all human beings or stock bitten by it. Although the parasites live in the gut and salivary glands of the fly, the latter suffers no inconvenience from their presence, and remains a source of danger for the rest of its life.

The book treats of the subject from the entomological point of view, laying stress upon the most remarkable fact of the life-history—viz., that the tsetse-flies nourish their young or larvae one at a time *in utero*, giving birth, at intervals of ten days or so, to full-grown larvae of the third instar, which hide away and pupate in suitable localities in the African forest belt. It is this fact which reduces the problem of control to one of studying the haunts of the flies themselves and of rendering their accustomed habitats unsuitable to them. About twenty well-marked species of *Glossina* are now known in Africa; a large part of the volume is given up to the detailed account of the specific differences, the figures of the male and female genitalia being particularly valuable. According to the structure of these organs, the author divides the species into three distinct groups, known as the *fusca* group, the *palpalis* group, and the *morsitans* group; by this means, with the aid of the very clear group-keys, any species of tsetse-fly can be determined (the males more readily than the females). A short but useful chapter discusses the technique of dissecting and mounting these parts. The plates give figures of the principal species, their larvae and puparia, with numerous details of both internal and external morphology, and are followed by an exhaustive series of photographs of the typical haunts and breeding-places of the flies. Four very clear maps are given showing the known distributions of the twenty species in Africa. The book is clearly written throughout, and is beautifully printed on a high-grade paper; both printing and plates reflect great credit on the publishers. We congratulate the author and his collaborators on the production of this most valuable work, which must be considered essential to all those, whether scientists or medical men, who are interested in the study of sleeping-sickness.

R. J. T.

VEGETATION OF POOR KNIGHTS ISLANDS.

By W. R. B. OLIVER, F.L.S.

A CERTAIN amount of interest attaches to outlying islands, for the reason that they are natural sanctuaries for many kinds of plants and animals which are unable to maintain themselves against the more hardy forms of life, including man, introduced into New Zealand. The more inaccessible the island the less frequently will it have been visited and the less will the vegetation and fauna have been altered by outside influence. Of the islands lying off the New Zealand coast perhaps the least frequented are the Poor Knights. The landing is not good; the islands are fifteen miles from the mainland, and far from any of the large centres of population. At one time the Maoris occupied the southern islet of the group, but they migrated to the mainland over a hundred years ago, and there have been no permanent residents on the islands since. Apart, therefore, from the effects of the Maori and the pigs he left behind him, the flora and fauna of the group are in their primeval state.

The present account is of a preliminary nature, and is based on observations by the members of an expedition made by Messrs. W. R. B. Oliver and H. Hamilton, of the Dominion Museum staff, in December

last. Through the kind services of Mr. W. M. Fraser, engineer to the Whangarei Harbour Board, the Board's launch "Kumi" was placed at the disposal of the expedition, and Mr. Fraser joined the party during its stay on Poor Knights Island.

The "Kumi" left Whangarei on the 29th November, but as the sea was rather choppy outside Bream Head the coast was followed northward and anchor cast at Horahora Point for the night. Next morning the fifteen miles of sea between the mainland and the Poor Knights was crossed, and a landing made on the northern end of the southern islet. Camp was pitched in some pohutukawa scrub, and collecting operations began forthwith. While the party was having its evening meal prior to the departure of the launch to Whangarei the dinghy was carried away by the incoming tide and drifted to sea. It was necessary to construct a raft to reach the launch, anchored well out off the rocks, and for this purpose a tin trunk and driftwood were used. On this cranky craft Mr. McDonald, the skipper, next day reached the launch and returned to Whangarei. The loss of the dinghy was a serious handicap to the party, as it prevented visits being made to the northern islet.

On the 5th December the launch again appeared off the landing, and as the weather promised to be fine it was decided to land on the northern islet. While the botanist of the party was well up on the side of the hill the others left for camp, and, finding a heavy swell running, and fearing an enforced stay if the sea increased, shifted the camp, including all the specimens with the one exception mentioned below, into the launch. This was not done without an element of danger; and during one trip, while, fortunately, the dinghy was empty, a large wave overturned it on to the rocks, the men who were loading it escaping without hurt. Meanwhile the botanist was marooned on the northern islet, and the sea was steadily increasing. However, at 4 p.m. he was successfully shipped, and the "Kumi" proceeded to Whangarei.

Through the oversight already referred to, when shipping the specimens no samples of rocks were brought back by the expedition. A general account only of the structure of the islands can therefore be given.

The rocks appear to be entirely volcanic. They are of a whitish colour, and probably rhyolitic in character. For the most part they form a very coarse breccia in which the included fragments are often of large size and of very various textures. No bedding-planes could be clearly distinguished, but from the general slope of the surface features it is concluded that the crater from which the eruptive materials were ejected lay to the eastward. The islands, therefore, represent fragments of the western slopes of a volcanic cone.

It is on record that a small amount of coal occurs in the group. This was not seen by any member of the expedition. If not some plant-remains involved in the breccia beds, there may be a thin seam similar to those found on the mainland opposite, and thus indicating that the Poor Knights volcano rests on a sedimentary base.

Some remarks on the suitability of the group as a sanctuary for native plants and animals may be included here. Thanks to the efforts of Mr. W. M. Fraser, the islands have been declared a scenic reserve, and Mr. Fraser has been appointed honorary caretaker. Situated as these islands are, at some distance from the coast, they are well placed for a bird sanctuary. Their extremely rough nature and want of good landing-places also ensures their being practically unmolested. They thus possess

most of the attributes of a permanent sanctuary. The primeval condition of the vegetation and its contained fauna has, however, been altered to some extent by the following agencies :—

(1.) Fires have destroyed a portion of the scrub in both of the main islets, and in its place has grown up a covering of flax, *Leptocarpus*, and other native plants, with a sprinkling of introduced species. Probably in time scrub will again take possession of these areas.

(2.) The Maoris, who occupied the island prior to about 1820, cleared considerable portions of the forest on the southern islet. This area has now again been replaced by scrub and low forest, but undoubtedly of a different type from the original covering. In the lower portions a

FIG. 1.—View of northern island of Poor Knights, from northern end of southern island,

second-growth scrub of broad-leaved types is prevalent, on the higher levels manuka persists. Possibly the Maori is responsible for the small number of species of land-birds now inhabiting the group.

(3.) By far the most destructive to plant and animal life of the agencies introduced by human occupation in the Poor Knights are the pigs, of which the last have not yet been exterminated, though an attempt to kill off the remaining pigs on the island is to be made this year. By comparing the flora and fauna of the southern islet, where pigs have roamed for more than a hundred years, with that on the northern islet, or portions of the southern islet which are inaccessible to these animals, the destructive effects can to a certain extent be gauged. The plants of the forest-floor, including seedlings of trees, are wellnigh extirpated ; some species, like the fern *Asplenium lucidum*, are abundant in the northern island and almost extinct on the southern. But the most serious effect of allowing pigs in a forest undoubtedly arises from the destruction of tree-seedlings. The whole physiognomy of the forest may be altered

and its power of regeneration greatly impaired. The effect of pigs on the fauna is best seen in the wiping-out of the breeding-grounds of burrowing-petrels, a process which involves the killing of many birds. The rare Buller's shearwater and other petrels are practically extinct on the southern islet, but abundant on other islets of the group. Gannets, gulls, and terns are prevented from breeding on the pig-infested islets. Lastly, the large land-snail, *Placostylus hongi*, has been exterminated in all localities accessible to pigs.

Over 120 species of ferns and flowering-plants were collected by the expedition. As a whole they present the following features when compared with the plants of the mainland opposite :—

(1.) No conifers are present, and a great many of the forest-trees of New Zealand, such as tawa, taraire, tawhere, rata, and many others, are also absent.

(2.) The main portion of the flora is composed of species most commonly found in the coastal districts of the mainland, but still there are notable absentees, such as akeake, rewarewa, houheria, kiekie, and the matata.

(3.) Perhaps the most interesting fact to be recorded is that many of the common trees on the Poor Knights are species that are fast becoming extinct on the mainland. The islands therefore constitute a natural museum for such plants as the whau, parapara, tawapou, and the broad-leaved maire. This category also includes some shrubs and herbs, such as *Carmichaelia Williamsi* and *Lepidium oleraceum*, and two species, *Hebe Bollonsi* and *Xeronema Callistemon*, confined to the Poor Knights.

(4.) Worthy of mention in the present connection is the fact that certain structural features, such as succulence, large size of leaves, and prostrate habit, are noticeable in certain species when compared with the same or related species on the mainland.

TALL FOREST.

Thanks to the rocky nature of the ground along the foot of an escarpment, an area of tall forest has been preserved in what was probably its original condition. ; for here there is no soil suitable for cultivation, and hence the Maori left the forest, so far as can be judged, intact. That it is no second growth is testified by the large size of the trees—huge pohutukawa, puriri, and broad-leaved maire being conspicuous members. The surface is for the most part composed of loose stones, soil being visible only here and there in the crevices. The foliage of the bigger trees forms a close leafy covering, though their trunks are fairly far apart, and there is very little undergrowth, the kawakawa and the fern *Asplenium flaccidum* being the only plants noted. Possibly pigs have contributed to this dearth of undergrowth. In addition to the karaka, mahoe, puriri, titoki, kohekohe, and wharangi, the following trees call for special notice :—

The tawapou (*Sideroxylon costatum*) is a tree that finds a refuge in islands lying off the coast. On the mainland it is found in various localities or headlands as far south as the East Cape district. It is a large tree on the Poor Knights. The wood is hard, and the bark when cut exudes copiously a white latex. It is the sole representative in New Zealand of a large tropical genus.

The coast milk-tree (*Paratrophis Banksi*) is one of those species which is now found mainly on islands, although it still exists in a few localities on the mainland. Several large trees were noticed on the southern islet of the Poor Knights.

The parapara (*Pisonia Brunoniana*) is a large tree on the Poor Knights. The leaves are large and membranous, being exceeded in size among New Zealand plants only by the puka. Two other interesting points about the parapara are the exceedingly soft nature of the wood, which on drying shrinks after the manner of pith, and is at the same time readily attacked by fungi; and the very sticky fruits, in which small birds may become entangled and perish through inability to free themselves.

The whau (*Entelea arborescens*) is one of the most beautiful of New Zealand native trees. The leaves are large, and remind one of those of the mulberry-tree, while the large white flowers are borne profusely in conspicuous bunches. The large spinous fruit is also a notable feature. The whau seem to be fast becoming extinct on the mainland, where it is found here and there along the coast of the North Island and in the Nelson District. It is pleasing to record, therefore, that it is abundant on the Poor Knights. Cattle and sheep appear to be its enemies on the mainland, as it is generally found in situations inaccessible to these animals. As is usual in fast-growing stems with soft wood, the leaf-scars are visible on trunks of considerable size, and the annual rings are well marked and widely spaced. The wood is very light, and hence was used for floats for fishing-nets by the Maoris.

The Poor Knights mapau (*Suttonia divaricata*) differs from the mainland form of the species in its habit of growth and in the leaves. On the Poor Knights it is a small tree with broad leaves over 1 in. in length. It takes a dominant part in much of the scrub or low forest on the islands. The wood is hard and of a pinkish colour, and the bark is hard and woody.

The broad-leaved maire (*Olea apetala*) is very scarce, only one plant—a large tree—being noticed on the Poor Knights. This is in all probability due to the depredations of pigs, as young plants are plentiful on Hen Island, where there are no pigs. The tree spreads out into a huge canopy of foliage from a large trunk which branches near the ground into numerous rather slender branches. The leaves are deep glossy green with wavy edges, and are very stiff and coriaceous, but at the time of my visit (December) the whole tree bore, as well as the old foliage, young shoots supporting yellowish-green leaves of a delicate texture. The wood is very hard, but, as in the pohutukawa, straight-grained pieces cannot be obtained. In addition to the localities mentioned, the broad-leaved maire is found at Whangarei Heads, Mokohinau, and Cuvier Island.

SECOND-GROWTH FOREST.

The broad valley leading inland from the landing on the northern end of the southern islet is filled with a low forest of a mixture of trees: this is undoubtedly second growth. Possibly manuka first replaced the original forest, and the present forest has succeeded it, though on the higher ground manuka still persists. There are abundant signs of the ground having been occupied by the Maori, and had he allowed native trees to grow among his plantations they would facilitate the replacement of the manuka. Soil covers the ground except for heaps of stones here and there looking like broken-down walls of terraces and whare-platforms. The bush is not nearly so tall as the forest under the escarpment, but the kinds of trees appear to be much more numerous, and there is a little undergrowth here and there.

The trees most commonly met with are the Poor Knights mapou, mahoe, karaka, whau, tawapou, parapara, cabbage-tree, porokaiwhiri, *Carmichaelia australis*, and kawakawa. Four species of tree-ferns were noticed; the punga (*Cyathea dealbata*) occurred plentifully in one locality, but only a few

specimens of the mamaku (*C. medullaris*), *Dicksonia squarrosa*, and *Hemitelia Smithi* were found. Several species of ferns of the family Polypodiaceae were observed in the undergrowth, but no filmy ferns were seen. This cannot be due to lack of atmospheric precipitation, but is probably due to the porous nature of the rocky ground, which quickly becomes dry, and possibly also to the sea-spray, which during rough weather drenches the vegetation for a considerable distance from the shore.

The cabbage-tree (*Cordyline australis*) grows to large dimensions, generally far overtopping the tall scrub in which it is found. Clusters here and there can be seen from a distance standing out by their yellowish-green foliage.

The porokaiwhiri (*Hedycarya arborea*) is common enough on the Poor Knights. The only noteworthy feature that I recorded was the large size of the leaves, the blade of which measures 6 in. in length by 3 in. in breadth.

The scrub form of the ngaio (*Myoporum laetum*) appears to be derivable from the prostrate shore form, for it is a slender shrub with long irregular branches of nearly even thickness. One does not find the fairly regular shrub that is frequently seen on the mainland. As showing further how this species can adapt itself to different conditions, in the tall forest of the Kermadec Islands it forms a lofty tree, 60 ft. tall, with a trunk 6 ft. in circumference.

MANUKA FOREST.

The higher portions of the island support manuka forest. This is undoubtedly a successor to some kind of scrub cleared away by the Maoris. Under ordinary circumstances it would be expected that it would eventually revert to a broad-leaved type of scrub or forest, but the process seems to be indefinitely delayed in dry soils. The principal trees are the manuka rauriki (*Leptospermum ericoides*) and the pohutukawa (*Metrosideros tomentosa*). There is a rather open undergrowth containing such shrubs as the mingi-mingi (*Leucopogon fasciculatus*), the Poor Knights mapou, *Corokia Cotoneaster*, *Carmichaelia australis*, *C. Williamsi*, and the rangiora (*Brachyglottis repanda*). On the ground are various ferns, grasses, and sedges. The present bare appearance of the ground is undoubtedly due to pigs, which have roamed over the island for more than a hundred years, destroying birds and vegetation.

COASTAL SCRUB.

The low woody vegetation growing along the shore may conveniently be describes as an association distinct from the forests which it borders, as it contains certain species of plants not found farther inland. It is also to be distinguished by its dense low growth, reaching from 1 ft. to 5 ft. or 6 ft. in height. Detached portions occur on rocky faces where there is not a continuous covering of soil. Characteristic plants are the ngaio, taupata, and *Hymenanthera novae-zelandiae*. Coastal scrub forms an almost impenetrable thicket along the shore, and is extensively developed in the northern islet, which is high and exposed, and contains considerable areas of steep slopes and cliffs. Succulence is a feature of some of the scrub plants, and is especially noticeable in the ngaio, hongehonge, and the rock-lily (*Arthropodium cirrhatum*). On the cliff-faces a number of plants of the tussock habit occur in the scrub, which is more or less open. Such plants include the rock-lily, toetoe-grass, *Danthonia bromoides*, toetoe-upuko-tangata, *Poa anceps*, and *Xeronema Callistemon*.

Along the coast, where the scrub thins out, a very handsome species of koromiko (*Hebe Bollonsi*) is found in abundance. It forms a compact

shrub with leaves broader and shorter than the common koromiko, and bears a profusion of large erect racemes of purplish flowers. In exposed places the leaves are much smaller than in more sheltered situations.

The broad-stemmed *Carmichaelia*, or broom (*Carmichaelia Williamsi*), is plentiful on the Poor Knights. It stands out from all other species of the genus by its broad stems and large flowers and pods. It was first discovered in the East Cape district, where it is not very common, and the only other locality in which it is known to exist is the Poor Knights, where it was first noticed by Dr. Cockayne.

The ngaio (*Myoporum laetum*) occurs both in the scrub and among the coastal rocks. The Poor Knights form of the ngaio exhibits features quite

FIG. 2.—*Hebe Bollonsi* growing on Poor Knights.

distinct from the ordinary plant. On the rocks it is a prostrate shrub with long sinuous branches of nearly even thickness throughout. These arise from the stem at a downward angle, and trail along the ground. A plant may thus be 1 ft. in height but cover several square yards of surface. The leaves of the Poor Knights form are large and broad, measuring 4 in. by $1\frac{1}{2}$ in., and the oil-glands are fewer and smaller than is usual. A similar prostrate form of the ngaio from Mokohinau has been described by Dr. Cockayne.

The mawhai (*Sicyos angulata*) is a trailing plant belonging to the pumpkin and gourd family. The stems are grooved and scabrid, and produce at each node a leaf, a branched tendril, and two racemes of flowers, one of which flowers much earlier than the other, so that one usually bears fruit while the other is in flower. The fruits are armed with barbed spines, and, especially when dry, are rather irritating to the skin, as they break off and remain in one's clothes like the spines of *Acaena*.

The rock-lily (*Arthropodium cirrhatum*) covers extensive areas on cliff-faces, especially on the northern islet. When in full bloom it is a fine sight, and very conspicuous from the sea.

Astelia Cunninghamii grows on rocky eminences on the southern island, sharing the space with *Xeronema*. The bases of the leaves form a bulb-like structure, especially in plants in dry situations.

Xeronema is perhaps the most remarkable plant brought back by the expedition. The existence of an unusual species was previously known to Mr. Fraser, and possibly to others who have visited the group, but no specimens appeared to have been brought to the mainland, and hence the identification of the plant remained unknown. Shortly after our party landed. Mr. Hamilton brought a specimen into camp from the top of the sea-cliff above our tent, and the following day I came across a large patch on a rocky knob near the summit of the island. Later Mr. Fraser piloted us to where the plant grew more abundantly, and good specimens and photographs were taken.

FIG. 3.—*Xeronema Callistemon* growing on cliffs, Poor Knights.

Xeronema forms large tussocks, perhaps 5 ft. or 6 ft. in diameter, consisting of leaves and flowering-stems 3 ft. to 4 ft. in height. It is thus quite a large plant—as large as a moderate-sized flax-bush, but with stiffer iris-like leaves forming a more compact tussock than does the flax-plant. The flowers are bright red in colour, and occur in heads up to 1 ft. in length. As in the rata, the conspicuous parts of the flowers are the stamens and pistil.

Not less remarkable than the appearance of the plant itself is its relationship, for the genus *Xeronema* was known hitherto only by a species occurring in the mountains of New Caledonia. The Poor Knights species differs in certain respects from its New Caledonia relative, and is, moreover, a larger plant. Speculation on the occurrence of these two related species in such distant localities is difficult to avoid. A former land connection between the two points would be a sufficient explanation, and such a connection is supported by the presence in the two areas of other similarly related plants and animals. The kauri, karaka, puka, and the land-snail *Placostylus* quickly come to mind, so that the discovery of *Xeronema* strengthens the argument for a former land extension north-eastwards from New Zealand, a theory accepted by both biologists and geologists as necessary to explain many problems connected with the flora and fauna of New Zealand. The question which next presents itself is, Why has *Xeronema* died out in the intervening area? Such a conspicuous plant could not fail to be noticed had it existed in New Zealand, Lord Howe Island, or Norfolk Island within historic times. Pigs would no doubt lessen its numbers, but could scarcely exterminate it, as it is abundant on the pig-infested Poor Knights on cliffs inaccessible to these animals. It perhaps should be numbered among species which can survive only in situations such as isolated island or mountain-tops, where one might suppose that life is less intense than elsewhere—species, perhaps, of waning vitality that have lost in the struggle for existence that is taking place where life conditions are favourable. But nothing definite can be said, and the biologist must admit frankly that he cannot say why one species should increase and another die out.

Cook's scurvy-grass (*Lepidium oleraceum*) is a plant which has been almost entirely exterminated on the mainland by sheep and cattle. It is found on many of the outlying islands, including the Poor Knights. This plant was apparently once very common on the mainland, as Captain Cook collected boat-loads of it for use as an antiscorbutic by the crew. It is now extinct or very scarce in the localities visited by Cook.

PHORMIUM SCRUB.

Where scrub has been burnt there has sprung up an association in which flax (*Phormium tenax*) is dominant. With it are associated a few shrubs, chiefly ngaio and *Carmichaelia australis*, and a number of grasses, sedges, and herbs, including *Sicyos angulata*, which trails over the other plants. The flax grows fairly densely, but is not tall, 3 ft. or 4 ft. being the average height of the bushes. The appearance of shrubs possibly indicates that the flax association will eventually be replaced by shrubs.

REED SWAMP.

In two places on the southern islet conditions are sufficiently wet for swamp to be found. Where a spring emerges from the base of the cliffs a small patch of raupo occurs, and at the mouth of the valley facing north is a larger area in which *Leptocarpus simplex* is the dominant plant. While the raupo is practically a pure association, the *Leptocarpus* is associated with quite a number of plants, including flax, toetoe, and various grasses, sedges, and herbs. Among the latter are tall upright slender plants of *Lobelia anceps* and *Samolus repens strictus*.

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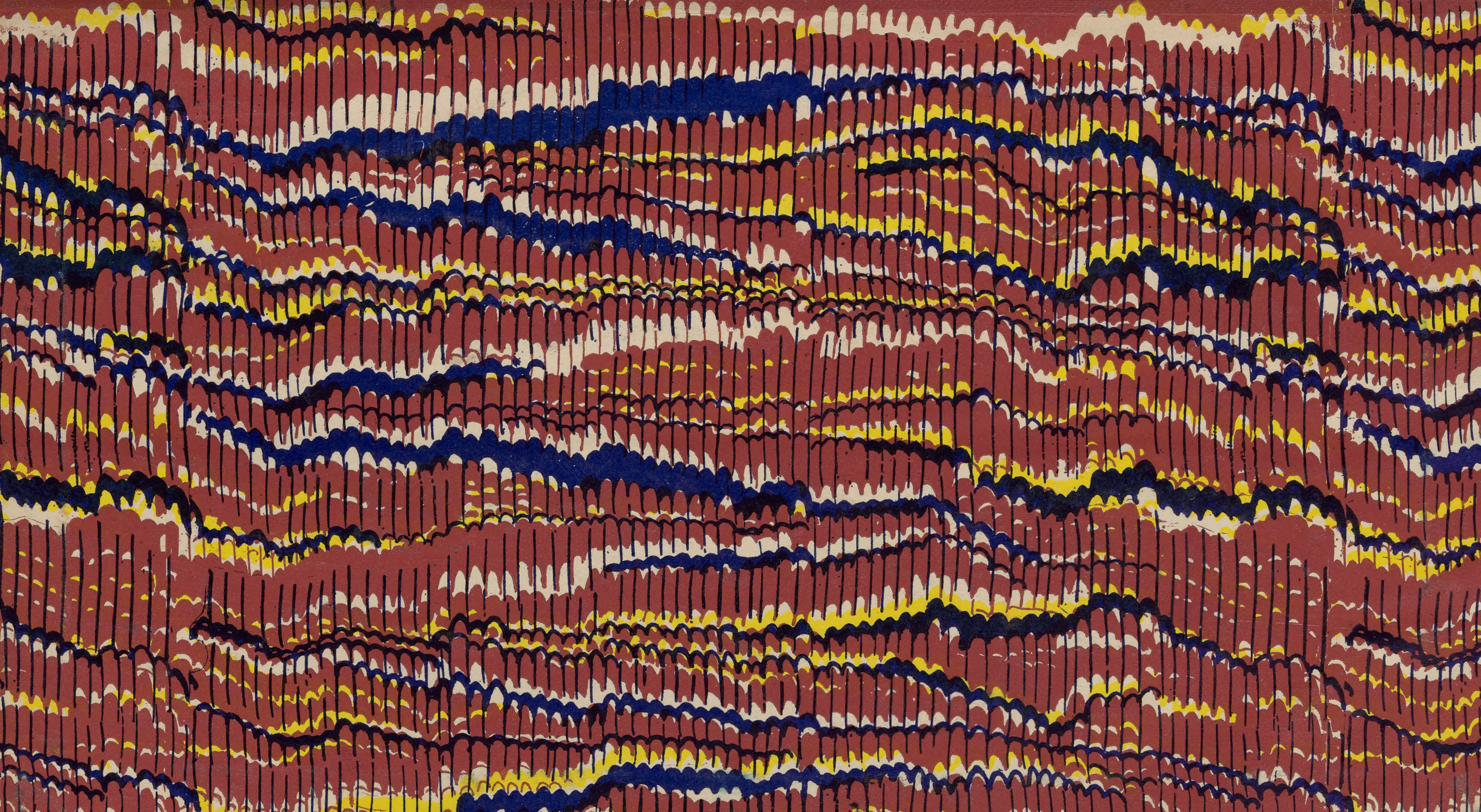

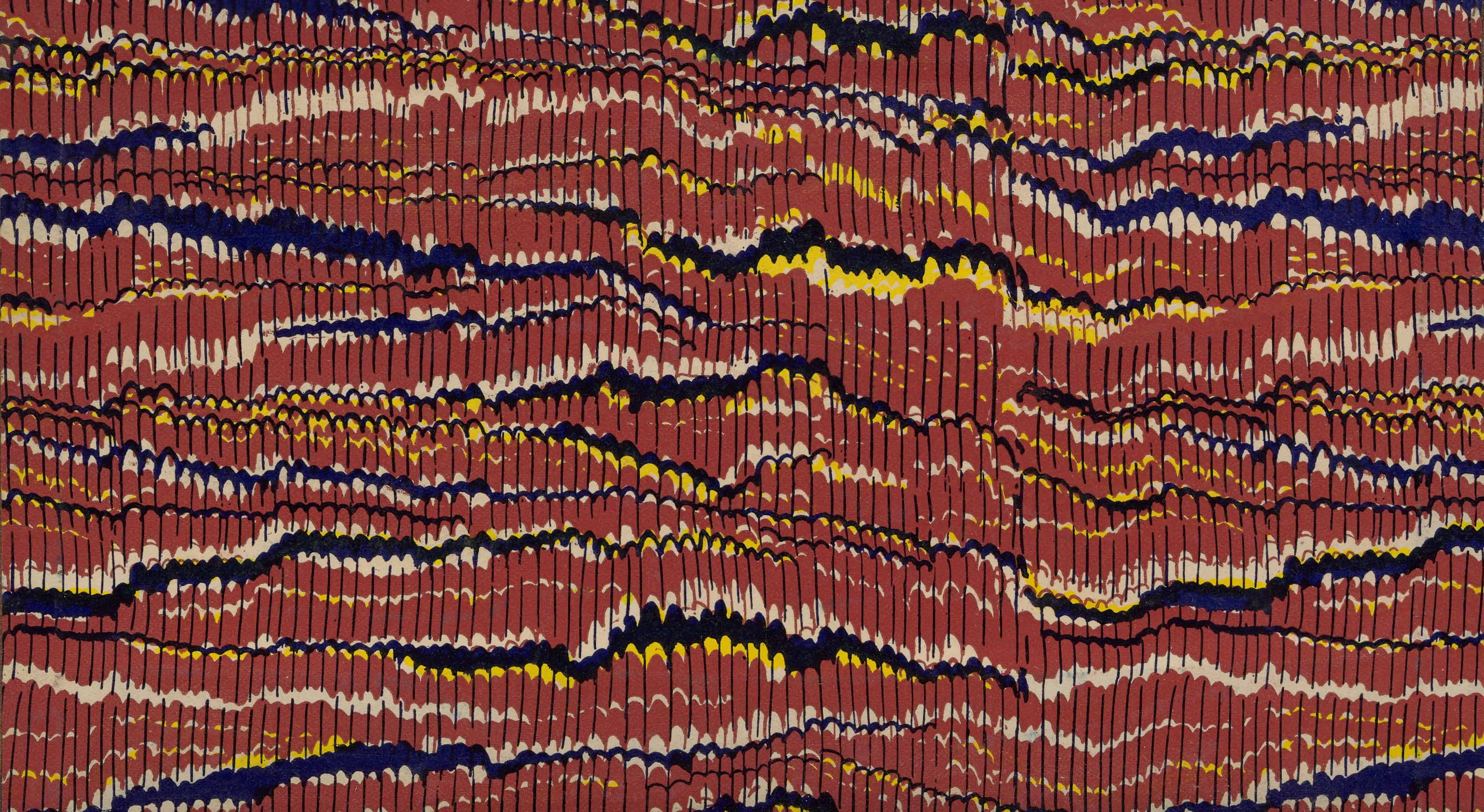

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